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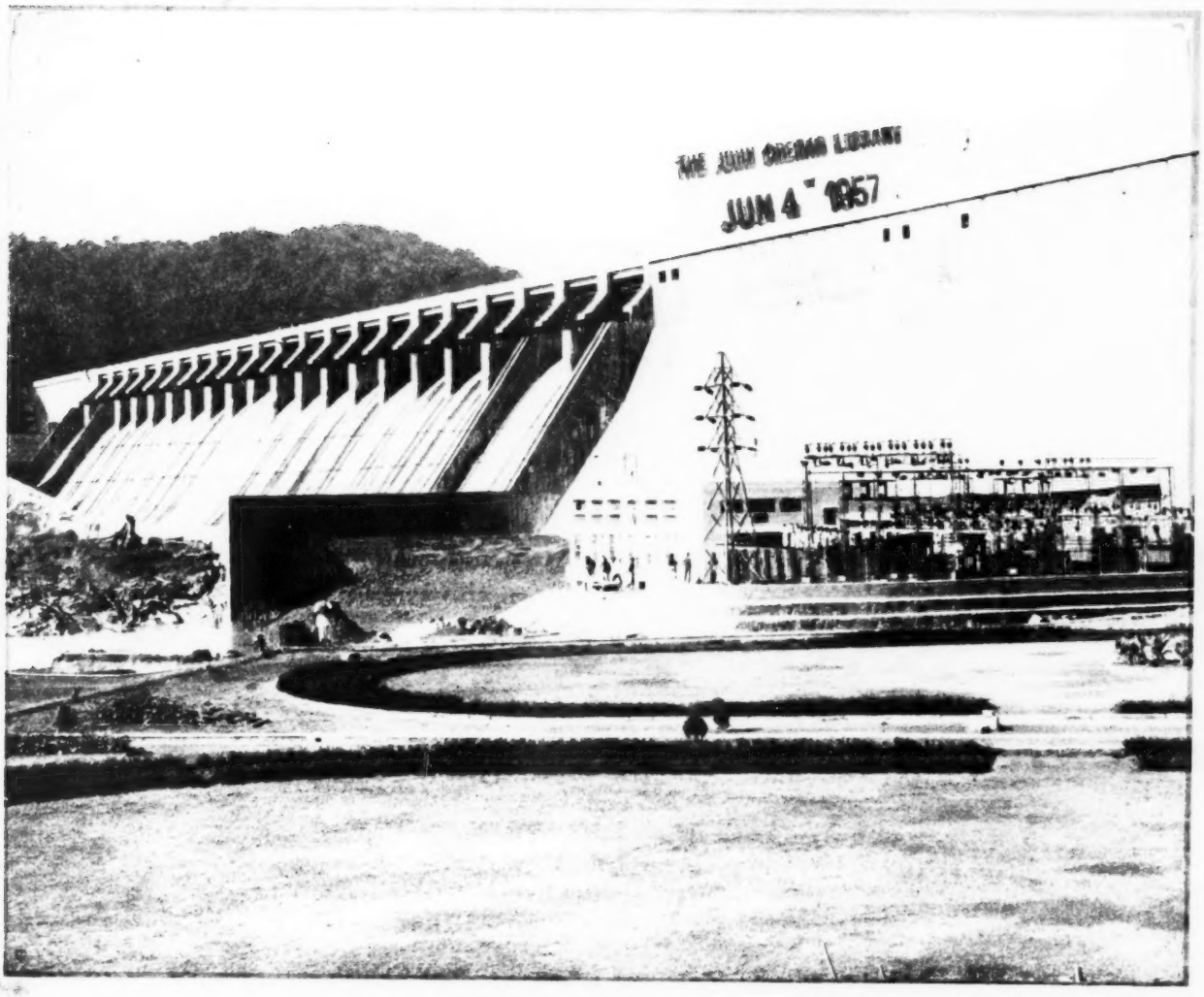
163

INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

DEDICATED TO MAYURAKSHI PROJECT
WEST BENGAL ELECTRICITY DEVELOPMENT NUMBER

VOL. VI. NO. 12 DECEMBER 1956 RUPEES THREE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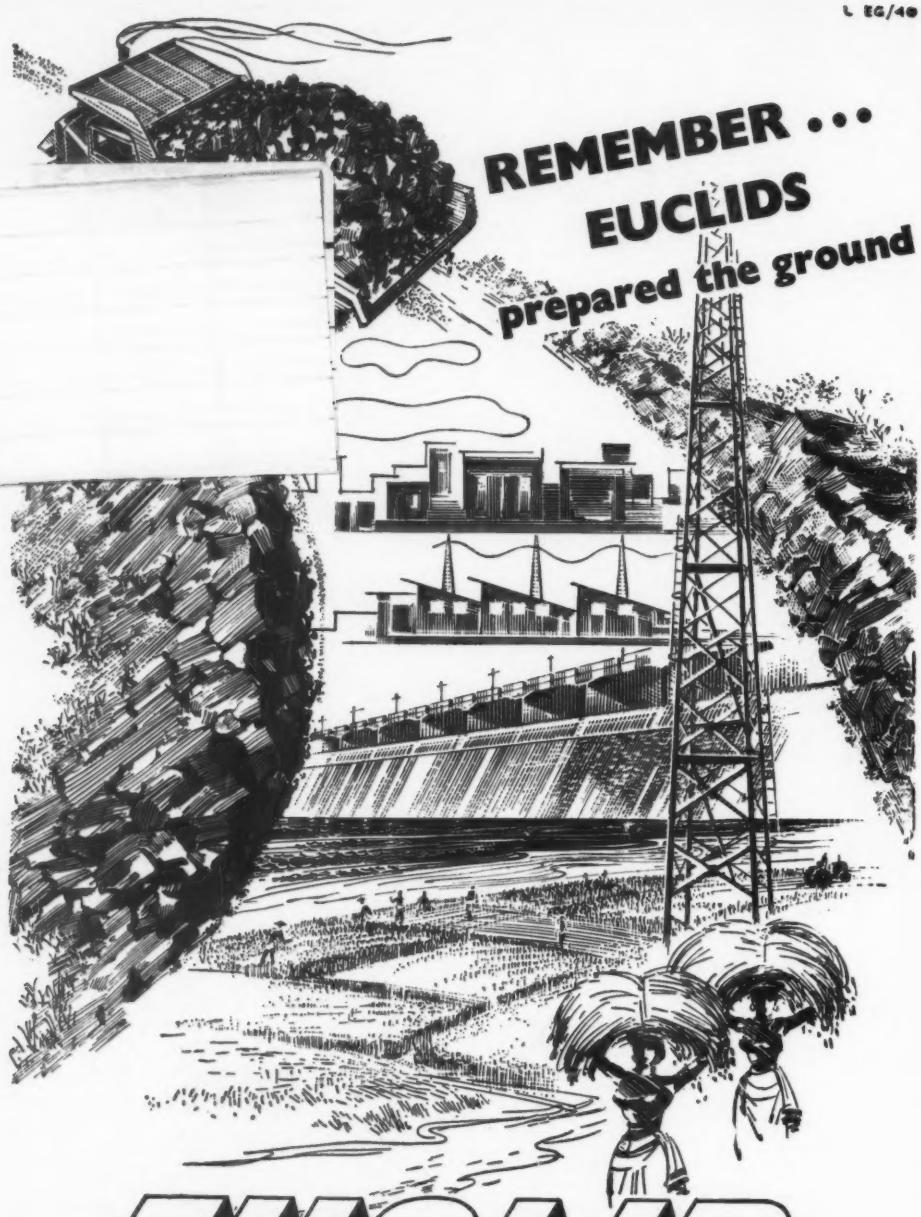
A VIEW OF THE MAYURAKSHI DAM AND POWER HOUSE



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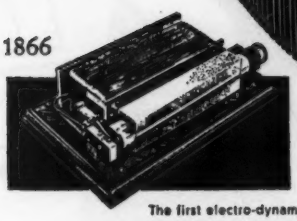
1866



The first electro-dynamo machine built in 1866 by Werner Siemens

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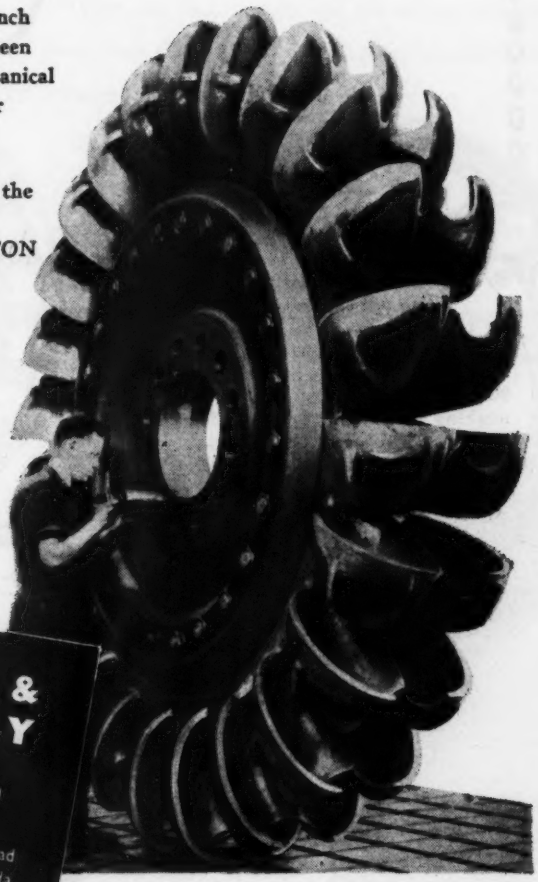

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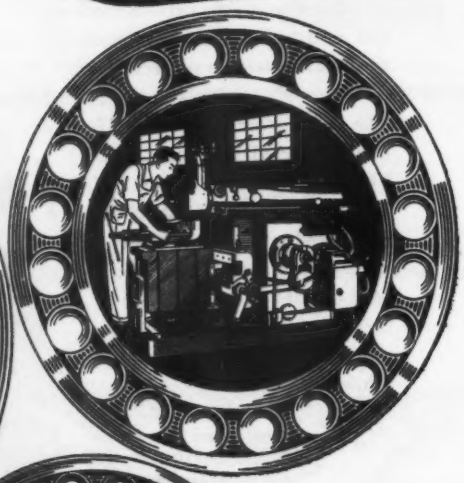

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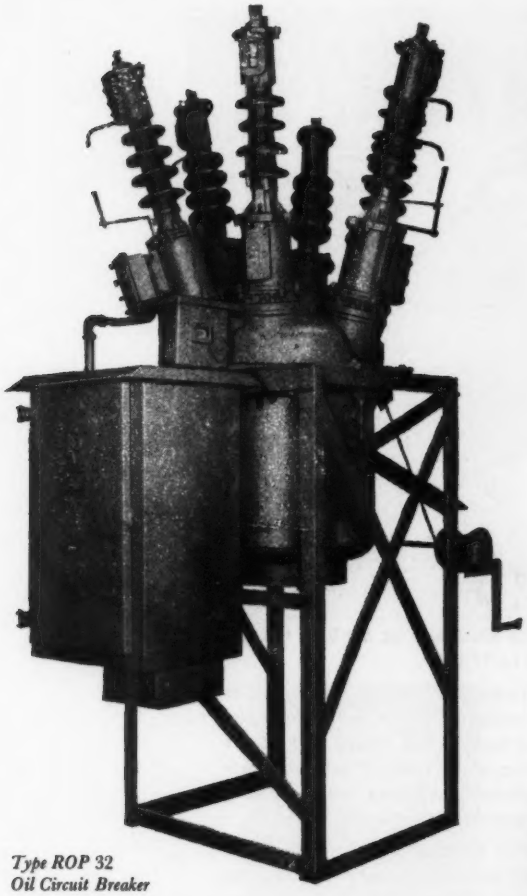
Ferguson Pailin have supplied switchgear for indoor and outdoor stations, including major hydro-electric schemes the world over. 'F. P.' is synonymous with first-class design, manufacture and performance of this essential equipment, ranging from extra high voltage switchgear for main grid supply systems down to low voltage switchgear for industrial purposes.



Type ROP 32
Oil Circuit Breaker

Two examples of 'Ferguson Pailin' switchgear, for varying duties, are illustrated here. They are :—

ROP 32 OIL CIRCUIT-BREAKER

Wherever 22 kV or 33 kV outdoor oil circuit-breakers for breaking capacities up to 750 MVA are required the merits of the 'ROP 32' breaker should be considered.

The design of this breaker provides for the optimum protection against adverse working conditions peculiar to countries in various parts of the world as well as maximum resistance to the effects of fluctuating temperatures and humidity.

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The circuit-breaker tank is of cylindrical shape and all three phases are brought into one tank, permitting the use of smaller framework thereby achieving compactness.

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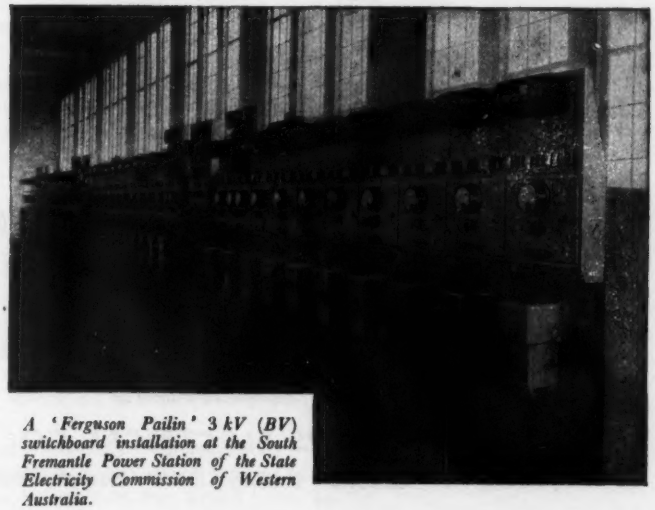
'Ferguson Pailin' Type BV switchgear is of the completely enclosed metalclad type. It is constructed on the unit principle and can readily be extended by units of similar rating, or by metalclad oil switches.

Vertical isolation of the breaker ensures minimum space requirements of the unit, whilst adequate interlocks safeguard against mal-operation.



A 'Ferguson Pailin' 3 kV (BV) switchboard installation at the South Fremantle Power Station of the State Electricity Commission of Western Australia.

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In 1924 it was Enfield who introduced to Britain the screened type of Paper Insulated Cable for 33kV working. In 1932 Enfield Cables built in England the first commercial Compression Cable in the world at 66kV. This has since been developed for working voltages up to 275kV.

Today the Enfield Factories at Brimsdown make a wide range of cables and flexibles but Enfield still keep a warm corner in their hearts—and incidentally a very busy section of their factories—for paper insulation.

Two interesting catalogues give you both the full story and a mass of useful technical data. Ask for Publications EN. 101 (Compression Cables) and EN. 102.

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FERRANTI

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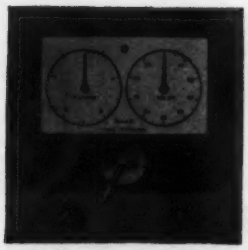
Conversion equipment supplied separately for modernising existing conventional test equipment.



One of the slave sub-standard counters which are mounted on a panel below the meters on test.

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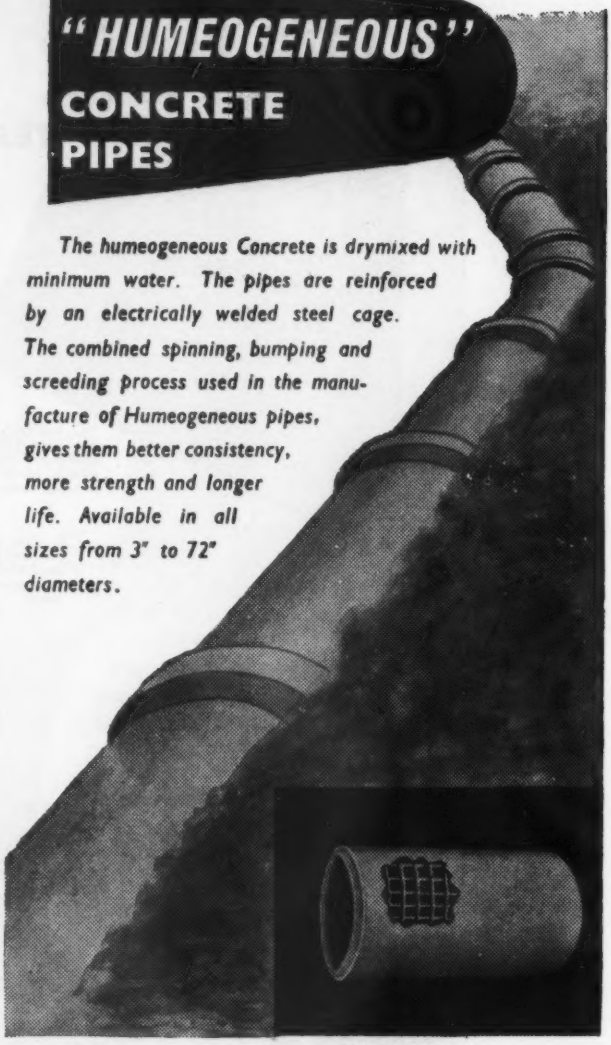

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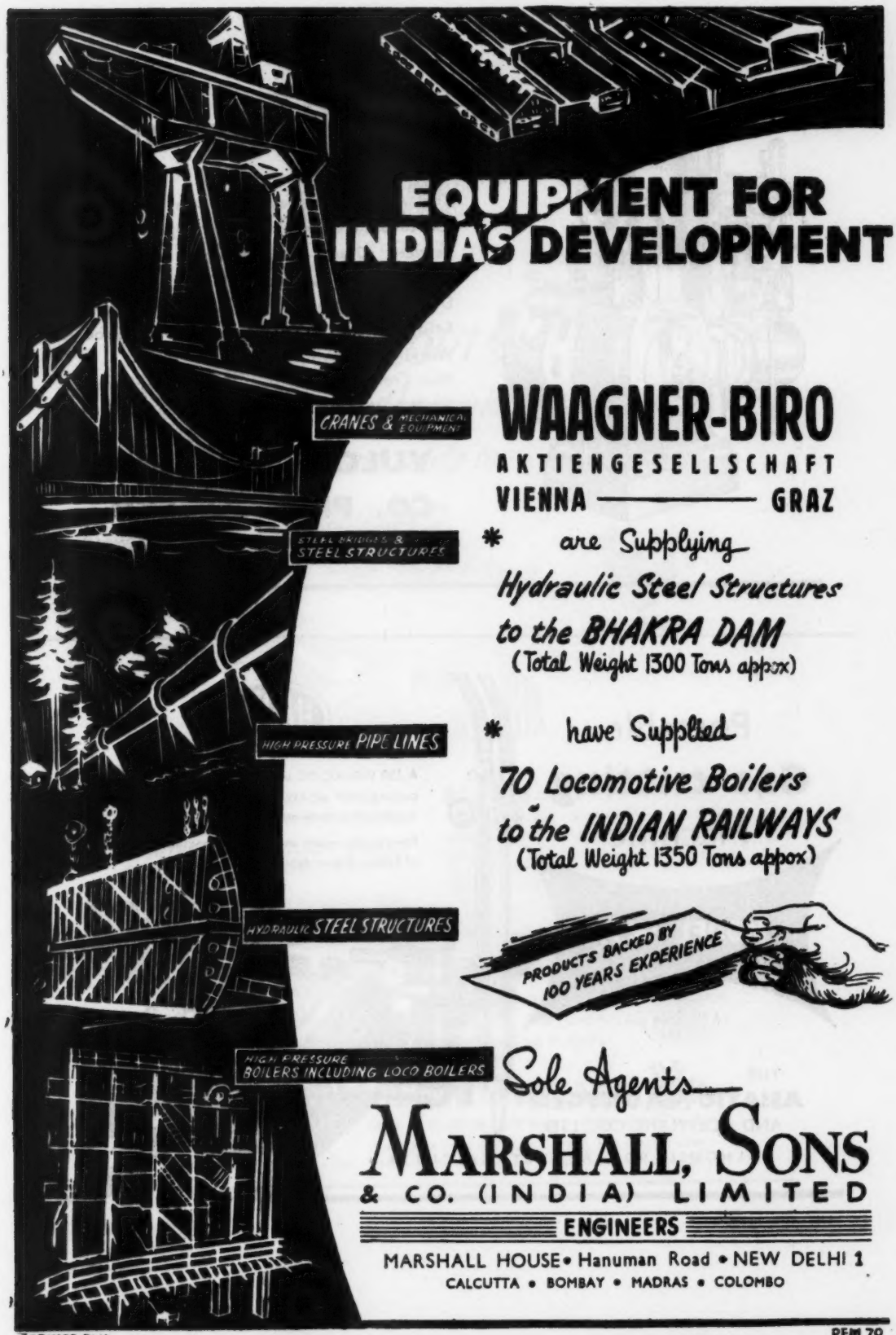
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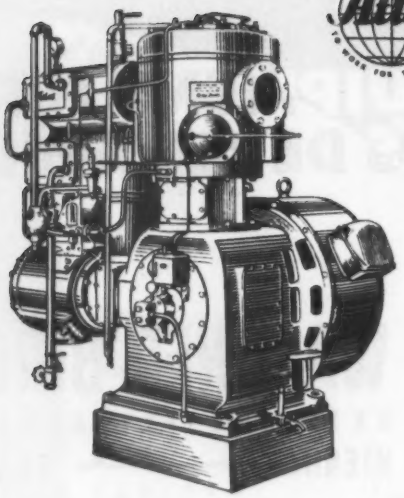

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The Atlas AR types with capacities from 330 to 3200 cft/min. and working pressures between 40 and 120 lbs./sq. inch are of the 2-stage, double-acting, watercooled design. Distinctive features of these machines are Reliability, Low Maintenance Costs, and Good Working Economy.

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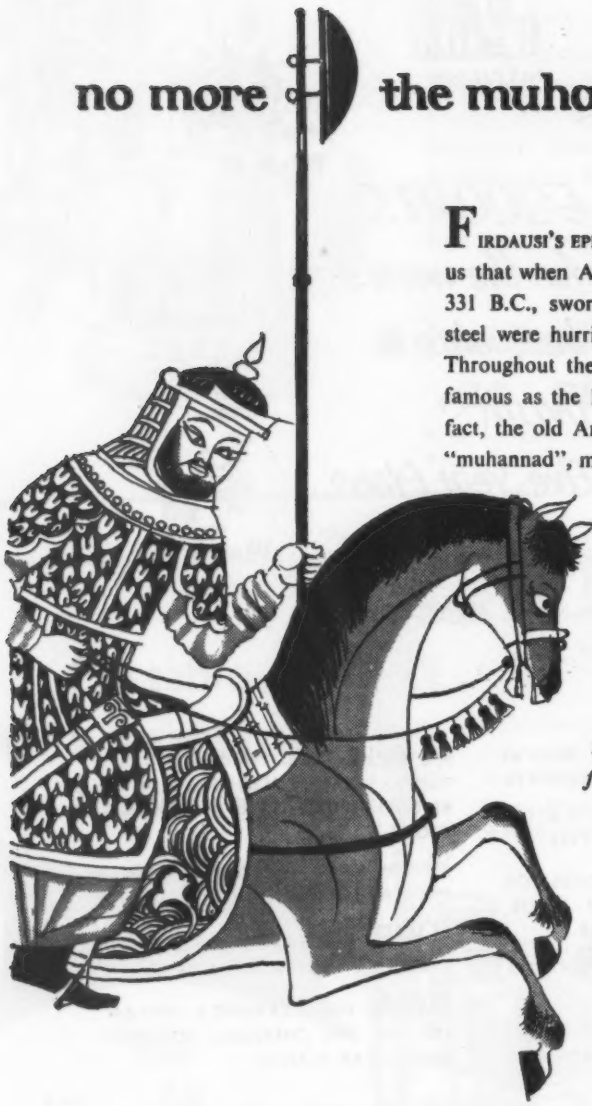

FIRDAUSI'S EPIC POEM, *Shah-Namah* tells us that when Alexander invaded Persia in 331 B.C., swords and other weapons of steel were hurriedly sent for from India. Throughout the civilized world India was famous as the home of quality steel. In fact, the old Arabic word for "sword" is "muhannad", meaning "from Hind."

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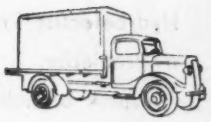

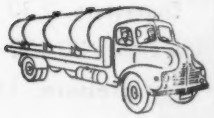

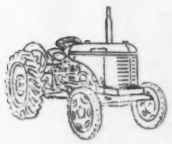

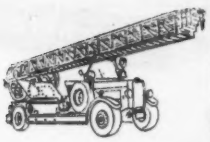

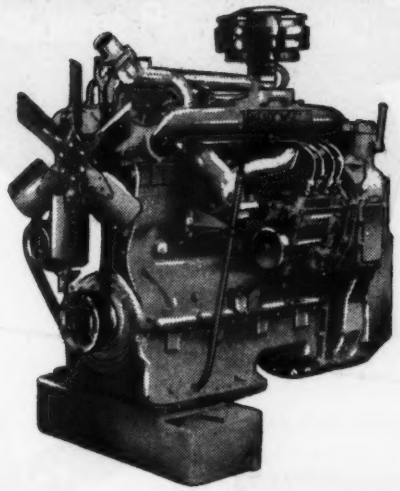

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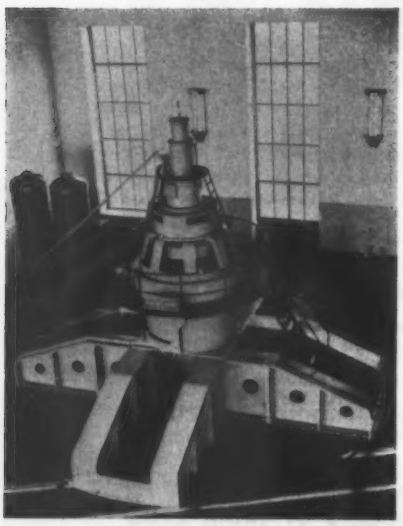

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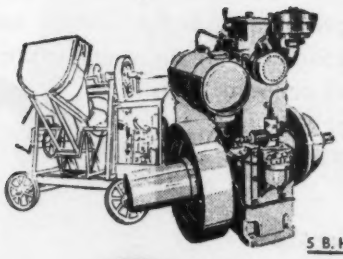

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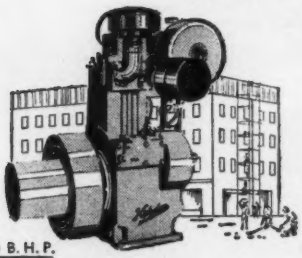

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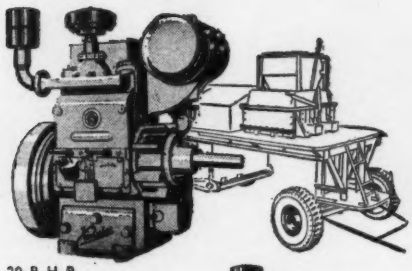

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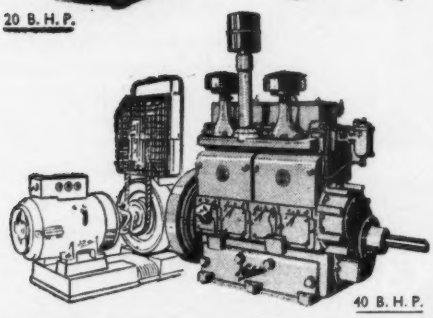

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Each belt is tailor-made to give you the optimum balance between various constructional features as best suited to your installation. Rigorous factory tests ensure top quality in supplies to the customer. Splicing at site is carried out by a Mobile Splicing team, an aspect of a thorough after-sales service in the field.

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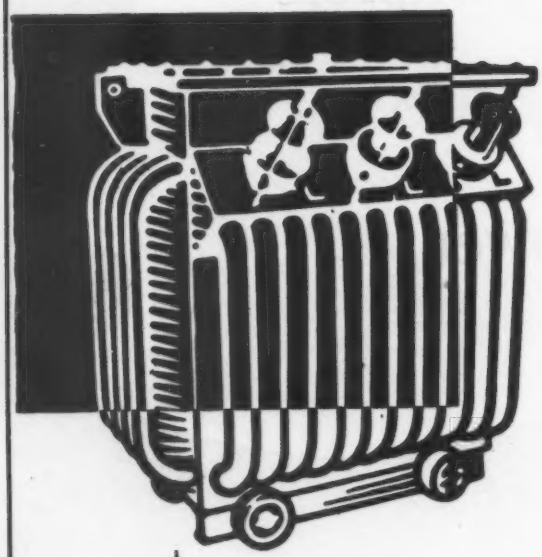

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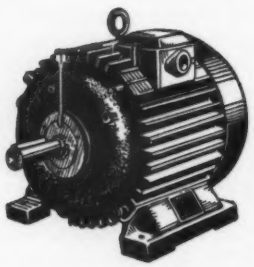

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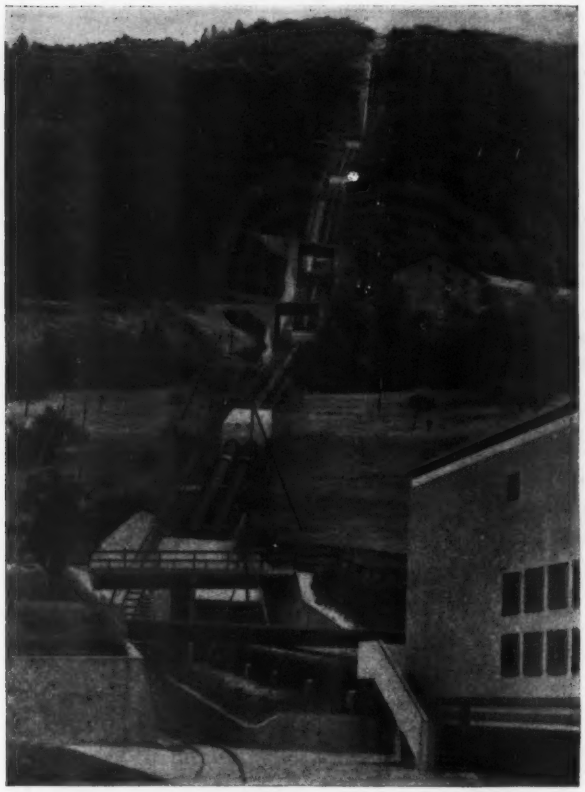

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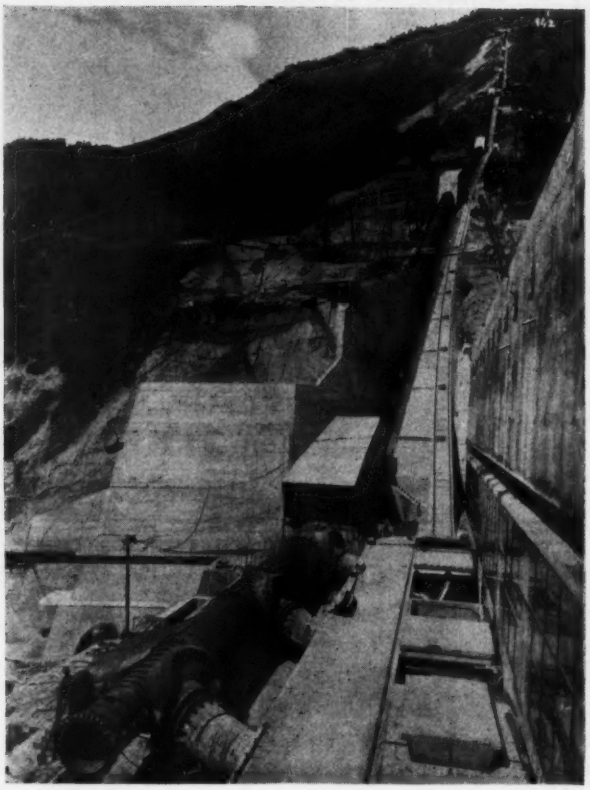

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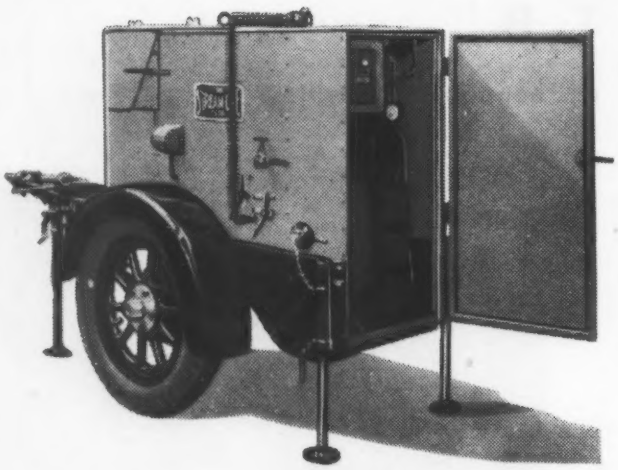

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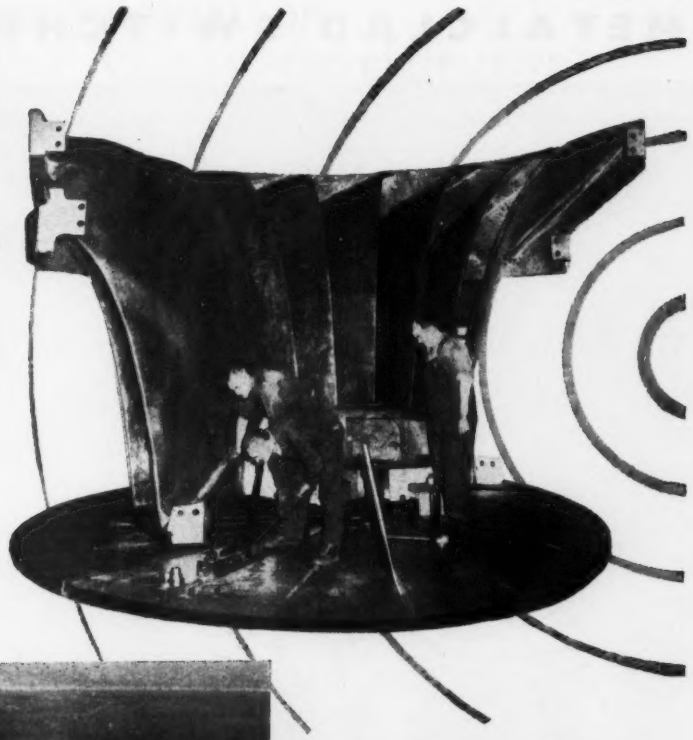

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Vol. VI | DECEMBER 1956 | No. 12

Dedicated to Mayurakshi Project

Devoted to Electricity Development in West Bengal in cooperation with the State Electricity Board

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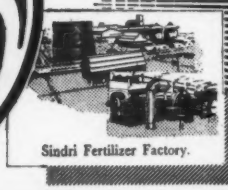
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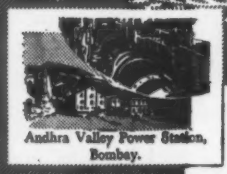
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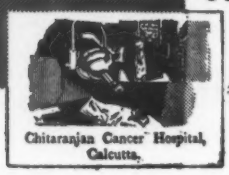
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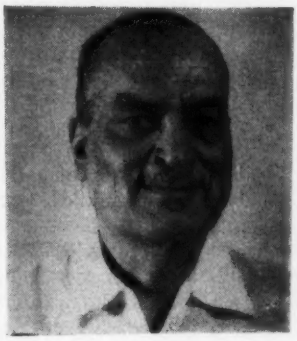
Let us all enter the tasks allotted to us with the idea that with the coming of Freedom and Liberty every one of us is on trial and it is up to us to make India great or make India look small. Jai Hind.

JAWAHARLAL NEHRU



I commend the enterprise of the Indian Journal of Power & River Valley Development in bringing out a Special Number on the West Bengal State Electricity Board. Though the Board was constituted only a few years ago, it is forging ahead. As a purveyor of light and power, it is trying to reach most rural and urban areas. Soon a time will come when the remotest village in West Bengal will enjoy the benefit of electric light and will hum with small industries based upon electric power. There is need that the public should be informed of the manifold activities of the Electricity Board. The Special Number is a welcome step in that direction.

B. C. ROY
Chief Minister
Government of West Bengal

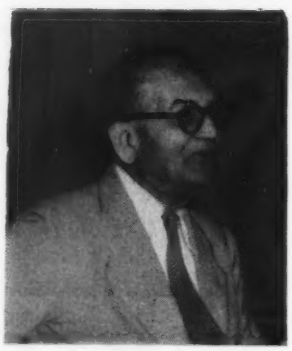
Ever since I arrived in India nearly four and a half years ago the Mayurakshi Project has been a concern of my mind. It was one of the projects in which your country and mine were co-operating for the benefit of the new India and therefore a part of the business I had to attend to as Canada's representative here. I first visited Messanjore in March of 1953. Since then the Mayurakshi Project has been a concern not only of my mind but of my heart.

I was at Messanjore again with my Minister, the Hon. L. B. Pearson on November 1, 1955. By then the work of the thousands who had toiled to build the dam was finished, and the Mayurakshi had become a rust red lake behind the dam and a domesticated trickle in front of it. Mr. Pearson was privileged to open the dam formally on that occasion and in doing so he was quick to note the honour conferred on my country by naming it the "Canada Dam."

Although the dam was now at work for India it had an appendage which was not yet ready to go to work. That was the hydro-electric plant at its foot. Canada had agreed to donate, at a cost of some thirty lakhs, the electrical equipment necessary for the plant to function effectively. By December 16, 1956 the plant was ready and on that day, Sir Dhiren N. Mitra, Chairman of the West Bengal Electricity Board, declared the Messanjore Power Station open. At the time I was somewhere in the air between India and Canada on my way to Ottawa to be there for the visit of your distinguished Prime Minister. I wish I could have been in two places at once for on that December day the work of over twenty-eight years of planning and striving to turn the resources of the Mayurakshi River to human benefit was completed. I shall always be proud that Canada participated in this great experience.

West Bengal's first major hydro-electric generating station is part of the Canada Dam, part of a number of Indo-Canadian cooperative endeavours, and part of India's mighty efforts to become a better home for her sons and daughters. My mission to India has almost run its course and perhaps by the time this is printed I shall have left your friendly shores. But I shall always remember the Canada Dam and in particular what Prime Minister Nehru said on the day that it was opened : "The dam will be a visible and enduring link of friendship between Canada and India. Let this friendship endure."

ESCOTT REID
High Commissioner for Canada in India



Quite apart from its technical perfection and its usefulness, the Mayurakshi Project is an example of that cooperation which every right-minded Bengalee and Biharee would like to see established between the States of Bengal and Bihar. The work-site is in the State of Bihar. The work has been undertaken by the State of West Bengal and the Hydel Project has been made possible by the generosity of the Government of Canada. The Project is, therefore, a monument of mutual help between two good neighbours and a member of the Commonwealth, geographically separated from us by seven seas. May this spirit of co-operation grow from more to more.

D. N. MITRA
Chairman
West Bengal State Electricity Board

ELECTRICITY IN WEST BENGAL

The series of contributions by West Bengal State Electricity Board's senior officers that follows in this issue gives a bird's eye view of the prospects and problems of generation, transmission and utilisation of electricity in this State. Their magnificent efforts are coming to fruition one by one. And it is also noticeable that a remarkable degree of foresight and imagination has been applied not only to face the problems of the present but also to anticipate the demands of the future. It is also interesting to note that the Board has attempted to delineate broadly the future contours of economic development in the State as a whole. Whether this broad outline conceived from the Electricity point of view coincides with the planning of other important fields of economic activity such as transport and communication, irrigation, industries, marketing, etc. needs to be scrutinized. If there arises serious structural disharmony between the different fields of development at a later stage, it may be too late to mend and at too great a cost. Therefore the coordination in such structural planning of basic categories of economic development should take place now rather than later. Let us hope that serious attention of the authorities would be directed towards this incipient problem.

Electricity is an important pre-condition of industrial development and better living. But so is transport and communication. Inland water transport has been practically elbowed out by the railway the deteriorating condition of the lower reaches of the rivers has further aggravated it. With the galloping development of the economy in India, there is heavy pressure on existing forms of transport even when these may be rapidly extended. Water transport thus needs to be taken up in right earnest on a large scale. But the more one studies this aspect the more he gets convinced that the Ganga Barrage scheme is the major key to it and to a host of other problems facing West Bengal. The Electricity Board has rightly stressed the idea of a dispersed development of industries and has therefore thought in terms of a North-South Grid. But is it not vitally linked up with the problem of good transport facilities between North and South of West Bengal?

In the Second and Third Plan periods the North Bengal hydro potentialites will be developed. That is as it should be. But industrial development in the North is based on certain types of industries such as Tea and Timber which have deep roots in the soil. The geological condition of the Himalayas is not stable, particularly in the eastern regions. Therefore electricity consumption in such developing industries has to be very carefully and cautiously nurtured in harmony with the conservation of the soil. Soil Conservation and afforestation are the most pressing tasks in these regions and yet their rate of progress is that of a snail. If use of electricity in the North would increase deforestation, we would rather plead for postponement of its generation. Even generation of hydro-electricity by damming rivers would not be so smooth-sailing unless we give up the compartmental and myopic vision that is so prevalent in our day. But utilisation and conservation of forests are not mutually exclusive.

In sum, electricity is a means to an end, the end being the growth of a prosperous and well dispersed community. The more it is consumed by the citizen in all walks of life, the better it is. But it should be so planned, phased and laid out that it harmonises with the other parallel means of development of the community. If this integral view is kept in the forefront not only by our Electricity Board but also by all other departments, and if these parallel efforts are further suitably coordinated by our Development Department, then West Bengal may again be able to look up from its morose, morbid and embittered outlook in which it has been enveloped so far due to factors beyond its control.

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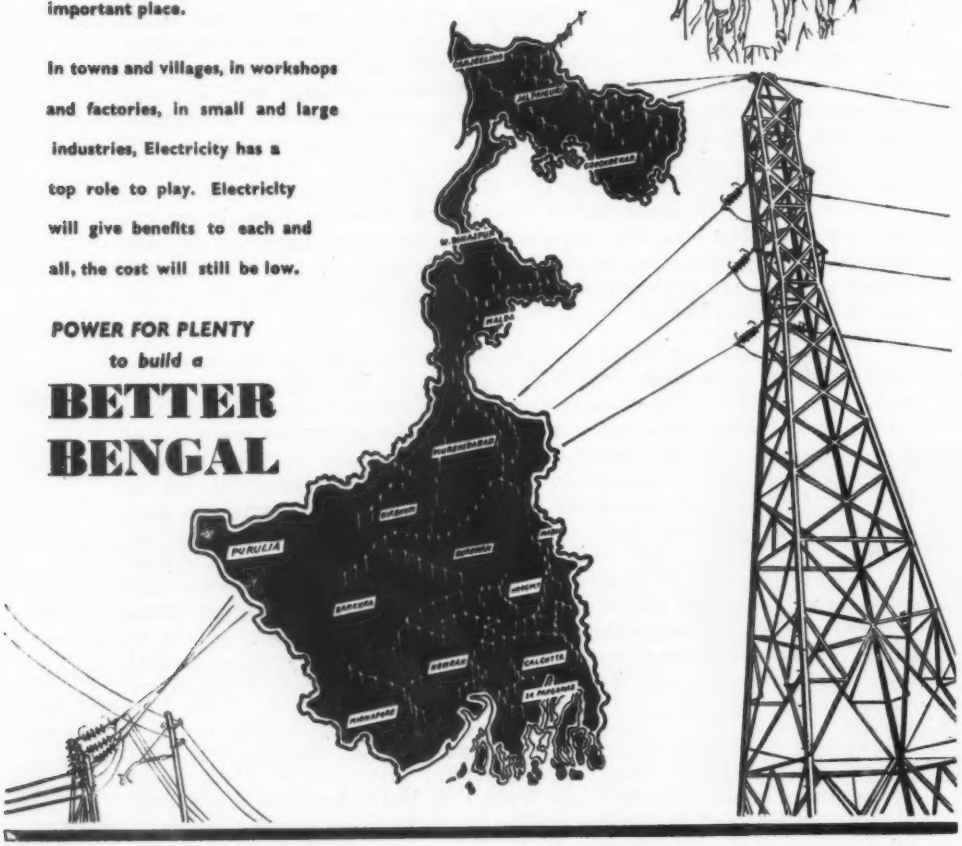

ISSUED BY THE GOVERNMENT OF WEST BENGAL

For a Brighter Bengal

By T. G. MUKHERJEA
Secretary, West Bengal State Electricity Board

Ours is the age of electricity. Everything we evaluate today in terms of electric development. Electricity is regarded as a yard-stick of a country's progress to prosperity. The planning for the growth of agriculture and industry or in a word the grand edifice of economic swaraj by judicious and well distributed network of electric power in the State has devolved on the W.B.S.E.B. The growth of energy resources is one of the basic foundations of any industrial development. As a purveyor of life and light the Electricity Board here stands for brighter life for all.

With the growth of electricity the age-long pattern of concentration of industries in certain specified areas is broken along with the manifold miseries of life which it brought in its train viz : mass migration, rooting out men, and women, squalor, de-humanisation, which process, in fine, has been a tragedy too deep for tears for our humanity. For development of decentralised, dispersed industry and for the progressive use of underground water resources for agricultural purposes, power supply for all areas is of prime importance. This is made possible mainly owing to the ubiquitous electric grid. We may now have a pattern evolved where the joy of life will not be denied to men and women. Our world may not be too much with us.

On the eve of her Industrial Revolution, India may well adopt the pattern with a judicious balance carefully determined between coal and electricity avoiding the aweful oedemas of the West and her preceding steam age. Our countryside may preserve its rural charm and character and remaining predominantly agricultural supply consumer goods in plenty with the touch of electricity provided. We may have throbbing looms behind the rural facade. We may well take a leaf out of the book of the Japan—that wonderful country in the East inhabited by that wonderful race, the Nipponese. Here the history's romance was enacted when a State was transformed almost overnight from mediaeval barbarism to highly modernised condition in the life-time of one emperor through the magical wand of work. All glory to them.

Coming to the planning in the West Bengal. Owing to the availability of coal in the western parts of the State, it is cheaper to generate power rather than hydro electricity in those regions. Whereas the northern districts are more suited for generation of water power, where owing to the configuration of the terrain, such supplies may be readily provided. For the lack of funds, as a part of the First Five-Year Plan, only the Mor Project has been executed so far which will yield power ranging from 2,000 to 4,000 kW. The first mile post is laid here. Besides, the expansion of the grids to interconnect efficient power stations for transmission and distribution of electricity over an area covering roughly 1,000 sq. miles has been provided ; a number of weak undertakings has been acquired ; a start has been made in the field of tubewell irrigation ; draining out a certain limited water-logged area in the Sunderbans has been undertaken. Energy is being progressively provided for the coal field area where an ever increasing demand for the same has to be met. The electricity sales which were 1.09 in 1948 has now shot up to 12.82 million in 1955. The number of consumers also is steadily on the increase. From 1,32,687 at the end of 1948 the number has risen to 2,46,210 at the end of 1955. The track of a century is thus being covered now.

Much leeway has to be made up still. Madras which had a flying start has gone miles ahead. Against Madras' hydro out-turn of 563 million units we have a meagre 7.8 million units. In West Bengal the power potentialities of the Himalayan rivers have just been fully explored. The question of extension of grid system to Maldah and Dinajpur districts is under contemplation. The details with regard to Farakka which should be our first priority, the Ganga being the life line for Calcutta and West Bengal, are still to be worked out. The idea of extension of the tube well irrigation system to Nadia and Murshidabad with a view to provide an increased sugar belt for the country has only been mooted. Madras has 16,300 pumps used for well irrigation whereas we have only up till now 12. The question of harnessing the Kangshabati river in Manbhum and Midnapur has been taken in hand. In the rural field, electrification has just been started in West Bengal. The total number of villages in the State receiving electricity is only 67 against Madras' 1,800. The table appended indicacates our relative position in the race for national rehabilitation on the electric track. The figures tell their own tales.

In the Second Five Year Plan we concentrate on increasing hydel capacity of the State. Against

Madras' 585 million kilowatts we have as noted a meagre 7.8 at the moment. Our immediate objective is to increase this capacity to 28 MW. With this object in view the execution of Jaldhaka Project is being taken in hand. By harnessing its water power ranging from 12 MW to 25 MW will be generated adding substantially to the power intake for the industrial purposes, especially of the neighbouring tea district in the Duars releasing thereby coal at present largely in use for conservation and better utilisation elsewhere. A senior officer was lately sent on deputation overseas for having advanced training in the line. A Central Testing and Research Laboratory is also being set up. This may also contain a showroom of electricity plants and appliances as also a well equipped library. Rural Electrification and Assisted Wiring Scheme are being popularised and an efficient Service Organisation may be set up before long. A factory for production of all electric appliances with the co-operation of the industrialists having experience in the line has been mooted. Simultaneously rationalisation of our tariff is being pursued, and a simplification of the tariff structures for small scale and cottage industries has been provided. Flat rate has been sanctioned for irrigation purposes. With possible reduction in the overhead charges and increased efficiency in the working of the service together with duly integrated distribution of power over all areas, lower rates of supply may well be a practical proposition.

In the sphere of the staff welfare, endeavours are being made to rally the staff around the altar of disciplined national service and to build up a healthy community life for all inculcating a team spirit of work. Incidentally, this will help us to consolidate our home front. A library with a view to increase the ceiling of knowledge for the individuals is being started. Efforts will also be made to have night schools for the technical assistants. The staff is being progressively brought to permanent footing and on the integrated pay scale as sanctioned. Lately a Contributory Provident Fund for them has been started. Comprehensive schemes of staff welfare and medical relief are under examination. It is expected that when these are implemented there may be rich dividend in efficiency for the Service. Here, following the Gandhian ideology, family and paternalistic relationship with strong loyalty between the man and the master may be developed—a healthy partnership with profit sharing.

Looking back, the Board can feel legitimately proud over its achievements. As against a total of 23 undertakings during the year 1954-55 the Board was working 78 undertakings at the end of the year 1955-56 with another 24 undertakings being fully equipped during that year for operation. The addition of 55 new undertakings during 1955-56 and equipping the 24 undertakings for commission entailed the setting up of an extensive network of h.t. and l.t. lines. 20 miles of 33 kV/dc lines, 154 miles of 33 kV/sc lines, 243 miles of 11 kV lines laid during the year bear testimony to the progress done so far. The expansion has been similarly marked by a steady rise in the number of distribution substations and the number of consumers served. The Board has set up 13 new diesel stations and 45 distribution substations during the year and the implementation of these schemes of the Board has benefited a population of over half a million besides providing direct employment to a little over 6,000 persons.

Within the grand facade of Free India of our dreams brighter Bengal is being built up today in our sphere. We are confident that the glow of freedom will lit up the faces of all.

Comparative Statistical Data in respect of Undertakings in West Bengal and Madras (including Andhra) based on recent figures.

	West Bengal (30,775 sq. miles)	*Madras including Andhra.* (1,27,790 *sq. miles*)	*No. that should be on the pro-rata basis.*
1. (*a*) Total number of villages in the State receiving electric supply ..	67	1,800	433.73
(*d*) Total number of towns in the State receiving electric supply ..	35(S) 56(P) 91	157	37.83
2. Total number of electric pumps used for well irrigation ..	12	16,300	3927.71
3. Total number of rural industries run on electricity ..	57	1,500	361.44
4. (*a*) Total output (million units) ..	1638.5	686	165.3
(*b*) Total output (hydro) million units ..	7.8	563	135.66
5. L.T. lines in miles ..	286	4,011	966.5
6. H.T. lines in miles ..	920	5,099	1228.67
7. Total number of consumers served	15,939(S) 246,778(P)		
..	262,717	275,695	66432.53

(S) indicates State
(P) indicates Private

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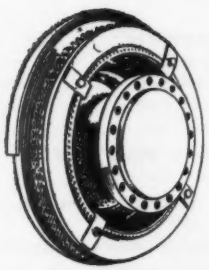

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HIRAKUD PROJECT NUMBER

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INDIAN JOURNAL OF POWER AND RIVER VALLEY DEVELOPMENT

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Prospects of Load Development in West Bengal

By A. K. BHAUMIK, B.Sc., B.Sc., (Eng.) (Lond.), M.I.E.E., M.I.E.., (Ind.), *Electrical Adviser and Chief Electrical Engnieer, Govt. of West Bengal*

The development of modern India will depend to a great extent on its industrial development and growth of electrical power. Both these factors depend on the per capita consumption of electricity. This figure was 14 in the year 1950-51 and is raised to 25 at the end of the First Plan period. It is expected that the per capita consumption of electricity will increase to 50 at the end of the Second Plan.

When the First Plan was prepared it was decided to add 7 million kW of power in 15 years but growth of development of industries has surpassed all expectations nd as the Second Plan has more industrial bias, this target of 7 million kW will have to be achieved much earlier than proposed. The total installed capacity of power plant in the country will be increased from 3.4 million kW to 6.8 million kW. in 1961, comprising 2.9 million kW under the public sector with a break-up of 2.1 million kW of hydro-electric plant and 800,000 kW of thermal plant.

The State of West Bengal has a population of 24.81 millions, 60% of which live in rural areas. 18% of the total population live in the city of Calcutta and its suburbs consuming 81% of the total energy utilised in the State. This is because of the concentration of large and heavy industries in and around the city of Calcutta. The annual per capita consumption of electricity in the city area is 300 units whereas the per capita consumption in other areas is only about 12. Out of 12 private supply companies generating power having a total installed capacity of 544 mW, Calcutta Electric Supply Corporation's installed capacity is 467 mW. At the end of the First Plan, the generating stations under the control of the State Electricity Board have an installed capacity of only 4296 kW. The installed capacity in kW. as it stood at the end of March 1956, is given below :

	Steam	*Oil*	*Hydro*
Electricity undertakings (Public Sector)	800 kW	5900 kW	800 kW
Electricity undertakings (Private Sector)	540221 kW	2172 kW	1640 kW

Hydro Power Generation

From the above table we can see that the generation by utilising water power in the State is insignificant compared to the total generating capacity in the State. As a step towards utilising the potential hydro power, Mayurakshi Irrigation-cum-Hydro-electric Project was undertaken by the State Government during the First Plan period at a cost of 16 crores of rupees of which 63 lakhs have been spent on the electrical side. The installed capacity of this hydro station is 4000 kW and firm power of 4000 kW will be available for 8 months and 2000 kW for the rest 4 months in the year.

The scheme is now complete and the power station has been commissioned. A 33 kV. double circuit line has been constructed between Massenjore power-station and Pandaveswar sub-station, where it is proposed to interconnect this system with that of D.V.C.

The second hydro-electric project undertaken by the State envisages harnessing of the Jaldhaka river in the border of India and Bhutan. The installed generating capacity will be 24,000 kW with two sets each of 12,000 kW. A firm power of 12,000 kW will be available throughout the year and 24,000 kW will be available for 8 months during the monsoon period. Investigation work is complete and the civil works have already been undertaken and the project is expected to be completed by the end of the Second Plan period.

The third hydro-electric project in the State will be materialised when the Balasun scheme is undertaken. Preliminary investigation work in connection with utilising this source of water power is being carried out and when the first phase of the scheme is complete, 5,000 kW of power will be available for 8 months and 2,500 kW for the rest of the year.

The only other body generating hydro power in the State is the Darjeeling Municipality. Their present installed capacity is 1,640 kW but all their sets have outlived their lives and need replacement. As there is a heavy shortage of power in the area, the sets will have to be utilised as long as it is possible. The Municipality has also a diesel power station having an installed power capacity of 500 kW.

At the end of the Second Plan, the availability of power by hydro generation in the State will be as follows :—

Under public sector	*Installed capacity*	*Firm capacity*
1. Mayurakshi ..	4000 kW.	2000 kW.
2. Jaldhaka ..	24000 ,,	12000 ,,
3. Balasun ..	5000 ,,	2500 ,,
4. Kurseong ..	1200 ,,	600 ,,
Total :	34200 kW.	17100 kW.
Under Darjeeling Municipality ..	2140 ,,	1640 ,,

Thermal Power Generation

The position of thermal generation in the State will be improved when the State Government's Durgapur Power Plant-cum-Coke Oven Project is completed. The project is now under execution and is expected to be complete by 1958-59. The purposes of the project are as follows :—

1. To provide process steam for chemical industries.
2. To use the coke oven waste gases in initial years, and
3. To provide cheap electrical power to industries, rural areas and for railway electrification.

Initially two 30,000 kW generating units will be installed. The boilers are designed for pulverized coal firing using a very low grade coal having an ash content of 35%. The generation voltage shall be 6,300 and will be stepped up to 132,000 and is proposed to be interconnected with the D.V.C's system. As this power station will be interconnected with D.V.C's system, a firm power of 60,000 kW will be available throughout the year. The Calcutta Electric Supply Corporation may also add to their generating capacity by installing a 50 mW set in one of their generating stations.

Diesel Power Generation

The generating capacity of the State will be further augmented by installation of isolated diesel sets in some of the localities which lie far away from the various grids operating in the State, as the capital cost involved does not justify extension of spur lines to those areas. At the end of the First Plan there were about 20 diesel power stations under the Board with an installed capacity of 5900 kW. During the implementation of the Second Plan some more places are expected to be electrified by diesel generating sets and the additional installed capacity will be 1,800 kW. Some of the diesel power stations will however be closed down as these places, being near the grids, will be connected to it. The total installed capacity of diesel power at the end of the Second Plan will be 6788 kW.

Thus the generation position at the end of the Second Plan will be as follows :

	Steam	*Oil*	*Hydro*
Public Sector	60,000 kW.	6,788 kW.	29,800 kW.
Private Sector	5,90,021 ,,	2,172 ,,	1,640 ,,

DEMAND FOR POWER

Coal field electrification

At pesent, the coal fields are served with electricity from two private licensees and the State Electricity Board has so far supplied power to only 4 coal-fields from their Pandaveswar substation, where bulk power is purchased from D.V.C. The present output of 38 million tons of coal in the country will have to be increased to 68 million tons by the end of the Second Plan and this will be only possible if the coal mines are more mechanised and electric appliances are used. Modernisation of mines by using more and more electricity can only ensure more output.

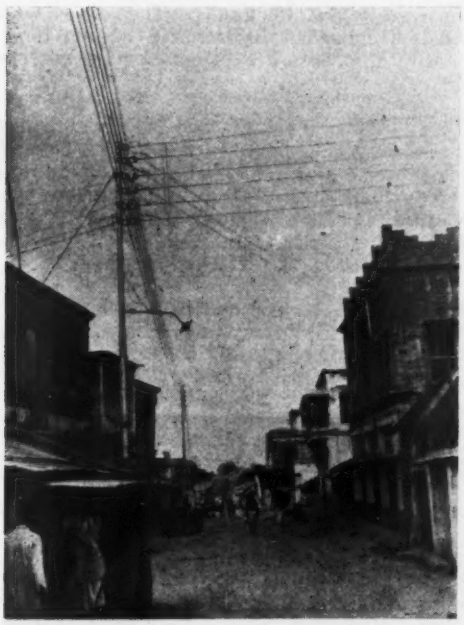
In connection with the electrification of coalfields, the excessive cost of the electric winders compel the owners to use steam power for winding and thus they are promped to think that when they are to maintain steam engine for the above purpose, there is no reason to use electricity for other purposes. A 600 BHP geared A.C. winder gives an output of 100 tons of coal per hour. In other countries electric winders are invariably used for purpose of lifting either coal or men. But in our country even those mines using electricity for other purposes do not use electric winders. But once the mine owners start to use electricity driven winders the demand for power on this account will be considerable. In the Rupnarayanpur area, electricity is purchased by State Electricity Board from Dishergarh Power Supply Co., and supply to Damagoria colliery having a present demand of 250 kW. There are more collieries in this area and a refractory and a chemical works are expected to be electrified during the Second Plan period. The estimated demand at the end of 1960-61 is 1469 kW. In the Churulia area, the coal fields and the Bengal refractory will be served with electricity by the State Electricity Board by purchasing power from Dishergarh Supply Co.

The possibility of load development in this area is very great and every effort is being made for developing load potential and it is expected that a demand of 5000 kW of power will come from coalfield electrification at the end of the Second Plan period.

Rural Electrification

As mentioned, the per capita consumption of electricity in the various parts of the State, outside the city of Calcutta, is 12 whereas the present all-India figure is 25 and the Government of India is trying to increase this figure to 50 by the end of the Second Plan period. If the same average is to be achieved in the State, it will be absolutely necessary for the electrification of rural areas. With a view to take electricity to the people even in rural and semi-urban areas, the Government of India recently sanctioned a sum of Rs. 163 lakhs of rupees. Under the scheme 60 places were undertaken for electrification during the end of the First Plan period. The places were very hurriedly chosen and most of them have since been electrified. Some of the places already electrified will bring very

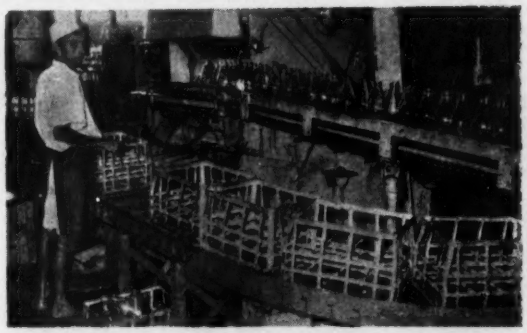
little revenue within the next few years and would not be self-sufficient for some time. In most of these places there will be mainly the domestic light and fan loads but from the results obtained under North Calcutta Electrification Scheme it is expected that small scale industries will be established in these areas in a short period of time. From the North Calcutta Electrification scheme we have found that apart from the fact that the number of domestic consumers have gone up considerably, the small scale industries such as wheat grinding, polishing, ice factory, ice candy and rice husking industries have grown up. Haringhata Dairy Farm, having a total herd strength of about 2000, takes power from the North Calcutta Grid and has a maximum demand of 200 kW. There are three incubators consuming 1,200 Watts for heaters in each. Four straw cutters and one grain crusher totalling about 57 H.P. are the other equipments using electricity. Under the North Calcutta Electrification scheme alone, the number of such small industries will be 300 to 400 in number and will provide employment for about 5,000 people.



Power Distribution at Sainthia

In European countries rural electrification load comes from farming and in some of these countries from co-operative farm. India is predominantly an agricultural country. In Bengal, just as in other parts of India, rural electrification has a special significance as it offers a solution for better irrigation facilities and thereby increasing food production and extending more employment facilities to the people living in rural areas and providing them with a better standard of living.

With the abolition of Zamindary system, the co-operative farms, whether under the public or private sector, will considerably grow and the problem of preservation of huge quantities of agricultutal products will have to be dealt with before these articles can be delivered to various parts of the State or outside. Cold-storage of perishable goods like fresh fruits, dried fruits, milk and dairy products, meat fish and eggs will be necessary. The possibilities of



Haringhata Dairy Farm

dehydration, preservation etc. of mango in the district of Malda may be investigated and if found technically suitable and economically justified, the demand for power arising out of refrigeration requirement will be considerable and increase the potential power demand in the State. Experience shows that an installation of 500 tons storage capacity requires power supply to the extent of 60-70 kW.

In our country some people are unemployed and some under-employed. The agricultural population, according to the present set up, remain unemployed during a considerable part of the year. For them development of cottage and small scale industries is necessary within the co-operatives. To name a few such cottage industries for which electricity may be used is silk throwing, knitting, tape weaving, button making, and potteries using small motors.

With the electrification of rural areas, people will not only have better amenities of life but will have better employment facilities in the new industries growing up in the area and thereby relieving the land from population pressure.

Irrigation

Another rural load can be developed if electricity is used for lift and tubewell irrigation. There are already five such tubewells working in Fulia area with an approximate intake of 15 kW each. For economic yield of crops, systematic irrigation either by sinking deep tube well or by lifting water from rivers, tanks and wells is absolutely necessary for supplementing the natural rainfall. A change over from food crop to cash crop particularly sugarcane may be considered and the possibilities of sugarcane cultivation and establishment of sugar factories may be looked into. Though the most important cash crop is sugarcane the growing of fibre crops may also be taken into consideration and if sufficient water is available by any of the above irrigation processes, the proposal will be a remunerative one. For economical working of tubewells it may be mentioned that 10-15 kW of power will be necessary to irrigate about 100 acres in Aush and 300 acres in Rabi.

These are potential factors on which will depend the growth of rural load. It is not only necessary to determine the final demand but rate of growth of demand

as well. Results obtained from pilot investigation carried out in the sample area will help to co-ordinate the demand for power, installation of generating sets and planning of transmission and sub-transmission

Uttarbhaga Pumping Station

lines. The estimated demand on account of this load will be 3,000 kW by the end of the Second Plan period but the demand may be much more if the Irrigation Department plans for development of irrigation by methods mentioned earlier.

A provision has been kept for electrification of 70 villages at a total capital cost of 80 lakhs under the Second Plan.

For assisting the people living in rural and semi-rural areas, the State Electricity Board has introduced Assisted Wiring Scheme by which anyone can have electricity by paying 10% of the actual cost in the first instalment and paying the rest in 24 instalments in case of a domestic consumer and in 60 instalments in case of an industrial consumer.

Assisted Wiring Scheme is working well and the number of consumers in our rural undertakings is growing very steadily. There are very few people living in rural and urban areas who can afford to spend a sum of Rs. 400-500 at a time to get the benefits of electricity. But as under Assisted Wiring Scheme, they have to pay only 10% at the beginning and pay the rest in instalments, the consumers find it easier to get connected to our system. The Board expects to provide consumers with electrical appliances on hire as it is done by the Area Board in U.K. in future when the financial position improves.

Demand for Power by Industries

Distribution of large and heavy industries is not at all even in the State. Industrial development depends on many factors such as transportation of raw materials, water, cheap electricity and dwelling places for thousands of workers. All these factors have contributed to the establishment of industries on the two banks of the river Hooghly. The tea industry is concentrated in the districts of Jalpaiguri and Darjeeling and there are some industries in and around Asansol as the coal mines are in the district of Burdwan.

It is however expected that West Bengal Government's endeavour to turn Durgapur into an industrial unit will have the effect of dispersing industries to that place. An aluminimum industry is expected to be established there, having a power demand of 15,000 kW. Durgapur Steel Factory will be served with power from D.V.C.

The planned industrial development in and around Durgapur will turn that part of the country into an industrial town. The various industries will find employment for thousands. The other factories include Hindusthan Refractories, a refractory proposed by M/s. Birla Bros., sanitary-ware works, sugar mills, yarn mills etc.

The towns of Bankura and Vishnupur which are now served with electricity from their own generating system will be fed from a grid now under erection. Power is now purchased from D.V.C. at Durgapur for meeting immediate demand. 60,000 kW of power which will be generated at Durgapur Power Station will be utilised by the following concerns :

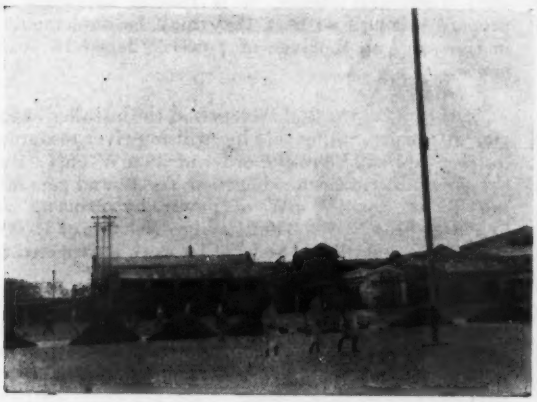
1. Damodar Valley Corporation	..	20 mW
2. State Electricity Board	..	6 mW
3. Coke Oven	..	3 mW
4. Station Auxiliaries	..	6 mW
5. Aluminium Industries	..	15 mW
6. Other Industries	..	10 mW

As the Power Station will be interconnected with D.V.C. system, the firm power will be 60,000 kW and the Power Station is expected to go into commission by 1958/59. It is also contemplated that the growth of power demand in this area will necessitate the installation of other sets in the station in a not too distant future, as it is definite that some of the by-products industries are to be developed along with the Steel factory in the very near future.

Bandel area has again some concentration of industries with J. K. Steel, Hind Motor, National Iron & Steel Co., all of which lie between Lillooah and Bandel. They are now served with power from Calcutta Electric Supply Co., though they are outside its licensed area. State Electricity Board proposes to take over these supplies from CESC and serve them from their system with power purchased from D.V.C. at Bandel. This will relieve CESC of some burden and load the Board's line more evenly. The estimated demand will be 13,000 kW at the end of the Second Plan.

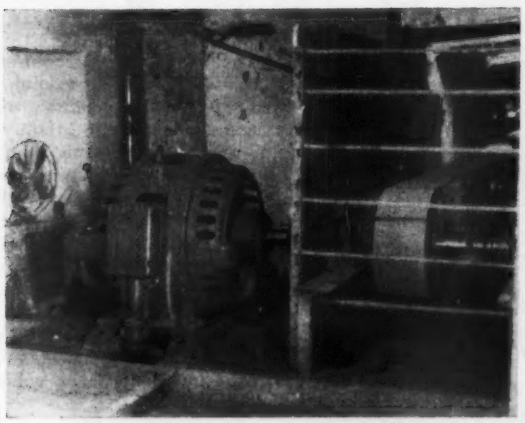
Rice Mills and other Small-Scale Industries in Burdwan and Birbhum districts

In the Mayurakshi area a large number of rice mills and other small-scale and medium industries now operating with steam driven machinery are expected to use electricity to an extent of 600 kW for the purpose. Morever, National Sugar Mill may require another 800 kW. The rice mill load in the Burdwan area will be near about 900 kW when most of the mills using steam and diesel driven machinery use electricity instead. By the end of Second Plan period the industrial demand in the Mayurakshi and Burdwan area due to these small-scale and medium industries will approximate to 3,000 kW and 1930 kW approximately.



Power Supply in a Rice Mill at Sainthia

There is a possibility of M/s. Birla Brothers establishing a Rayon factory near Mogra and the load is expected to be 2,000 kW at the end of the Second Plan.



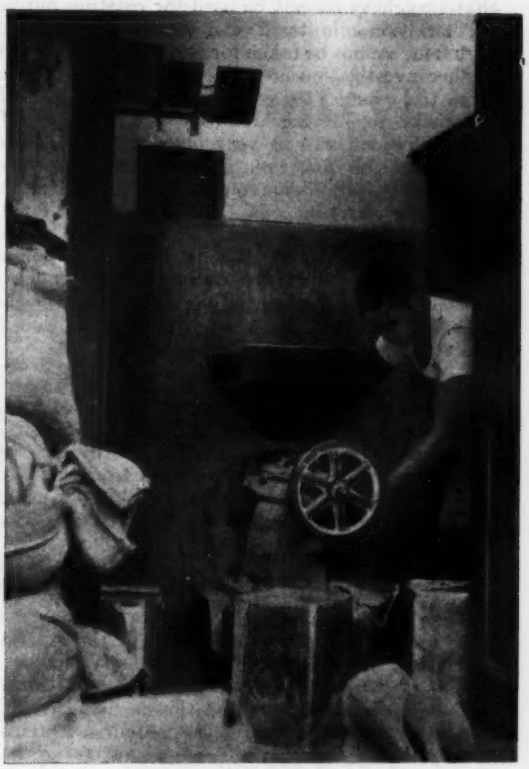
Power Supply in a Rice Mill—inside view.

Railway Electrification

In connection with the electrification of railways, the aggregate demand by the end of 1960-61 will be 62,000 kW. This includes electrification of the following sections:

(1) Howrah-Burdwan
(2) Suburban lines in Seaklah division
(3) Burdwan—Asansol
(4) Howrah—Kharagpur

The State Electricity Board will supply 8,420 kW through its grids operating in the north and south of Calcutta. The rest of Railways' demand will be met by Calcutta Electric Supply and DVC.



Wheat Grinding

Tea Estate Electrification

There are 265 tea estates in the districts of Darjeeling and Jalpaiguri, but very few of them use electric power for the processing purposes and most of them use wood as fuel for drying and roasting of tea leaves. The cost of coal or oil at the site has gone up considerably and the Government has further restricted unplanned cutting down of trees in the forest areas as the wood resources of the country is getting depleted. In view of the above facts, the owners of the estates will ultimately have to connect their factories to the electric grid of the State Electricity Board. The process of fermentation of tea leaves require control of temperature and humidity for better flavour and quality. This will require air conditioning of factories. The tea estates are very widely scattered throughout these two districts and though only a 50% of them are expected to be connected to the operating grids in the near future the fact that subtransmission lines must be extended to include the remaining estates will be kept in view.

In the tea industry there is a great possibility of utilisation of electric power if electricity is used for roasting purposes. Only one Tea Estate made use of a 400 kW electric heater for the purpose.

The Darjeeling Electric Supply which was facing shortage of power could not supply power to this Tea Estate for the purpose and they had to abandon the scheme. The Indian Tea Association is very much enthusiastic of getting connected to the future grid system and expect that electricity can be utilised with economy for the roasting of tea leaves. It is sometimes argued that electricity cannot be used for roasting purposes till an economic tariff can be offered. But this argument cannot be taken for granted without making further investigation into the case. It will be beneficial some tea estates, for experimental purposes, utilise electricity for drying and roasting of leaves. The result obtained will be very much useful for future assessment of load on this account and future planning of transmission routes. The engineers of the Board are carrying out extensive survey for the purpose of development of this load and the co-operation of the owners of the tea estates is absolutely essential. The owners are sometimes very much reluctant to invest capital for converting their machineries to electrical drive though they know that the operation cost will definitely be reduced.

All these tea estates along with other industries and rural areas and towns having deficit power supply will be served with electricity from the transmission system into which power will be fed from the Hydro Electric power stations at Jaldhaka, Balasun, Kurseong and Darjeeling at the end of the Second Plan period.

Timber Industry in North Bengal

There is a great possibility also of establishing large saw mills and timber works in the Northern districts of West Bengal. Establishment of plywood factory, factory for producing matches and making tea chests is also expected. From data available from other parts of India, such as in Madras, a plywood factory with a capacity to produce 200,000 sq. ft. of ply wood per month will have a connected load of 125 kW. There is a huge shortage of electric power in in the Darjeeling, Kurseong and Siliguri areas and the future demand arising out of the development of various industries mentioned above cannot be met unless the Balasun Hydro-electric Scheme materialises. This scheme has not yet been sanctioned by the Planning Commission but is expected to be taken in hand by the end of the 2nd Plan Period.

Already there is a Hydro Power Station in Kurseong having an installed capacity of 800 kW and the capatiey will be increased to 1,200 kW very soon. This Hydro Power Station is connected with Siliguri by a 33 kV transmission line and some of the tea estates are now supplied from this scheme.

A sample load survey was carried out jointly by the engineers of the Central Water & Power Commission and the engineers of the Board and a rough estimate of demand for power by tea estates to be supplied from Jaldhaka and Balasun was made.

The members of C.W.P.C. Survey Party have been very cautious in assessing power demand on this account but it is expected that the development of load on this account will be much more than anticipated at the end of the 3rd plan period.

The demand for power in the northern districts o. West Bengal can be met from the firm power which will be available from the interconnected grid system into which power will be injected from the 4 hydro-power stations. But further load demand is certain and from the experience of the past, it will be seen that once the power grid is in operation, demand for power grows at a much more rapid rate than can be visualized beforehand, because in our case past experience can never be our future guide. It is therefore necessary to carry out investigations for utilising the power potential of the other rivers of North Bengal viz : Tista and others. It is further necessary to prepare schemes so that they may be implemented in time and no shortage of power is faced 15 years hence.

At the end of the 2nd Plan period the installed capacity of the generating sets by utilising river resources in the State will be in the order of 36 mW only. But the possibility of harnessing river Teesta and generating about 300-400 mW of power by utilising an available head of 300-350 ft. and a discharge of 15,000 cusecs remains. The investigation work is expected to be taken in hand in the Second Plan period.

Apart from the fact that there will be considerable demand for power by the Tea Estates and other industries in N. Bengal, a considerable amount of power may have to be transmitted to the Southern districts of the State by a 275 kV transmission line to meet the growing demand of the industrial city of Calcutta and the surrounding areas. The rate of growth of load per year in the city of Calcutta and its surrounding areas is approximately 30 mW. So from 1960 onwards to 1970 the provision of power in the neighbourhood of 400 mW has to be made for the Calcutta area itself.

It has been a long practice in the European countries to interconnect generating stations for the pooling of spare plant and generating power at the most economical station. In that case considerable economy is achieved by generating power at the most economical station and transmitting the same to distant areas where generation costs are higher. In our country the question of load sheding has not yet arisen, but in the years to come with the development of industries, irrigation and new townships, the demand for power is expected to grow considerably in the areas surrounding Calcutta. The investigation carried out in U.K. and U.S.A. show that the cost of extra higher voltage system to meet the requirements would be no more and probably less than an equivalent lesser voltage superimposed system.

The State Electricity Board is planning the transmission and sub-transmission lines in such a way that in future wherever any demand for power comes from intending consumers, this can be efficiently met with, and it is expected that in future as the per capita consumption of electricity grows the demand for power will be much more than can be anticipated by using our past experience of growth as our yard stick.

Carrying coal for the country

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to feed all the ovens, furnaces and boilers..is the day-and-night job for us.

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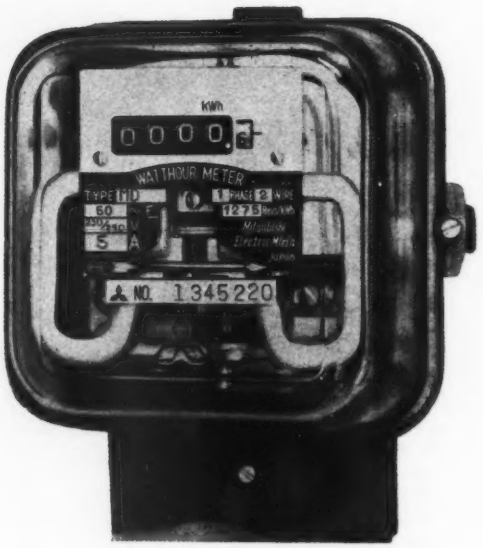
ETC., ETC.



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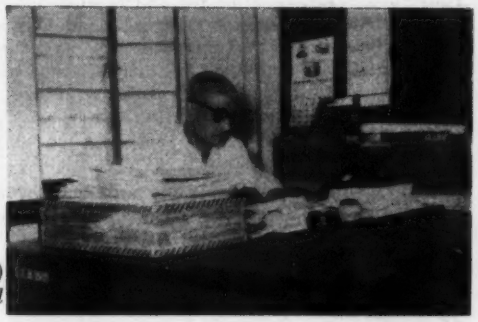
Mayurakshi Hydro-Electric Power Station



By P. C. GUHA, B.Sc. (Cal), B.Sc. Eng (Manch), M.I.E. (Ind.)
Superintending Engineer, West Bengal State Electricity Board

The multipurpose Mayurakshi Reservoir Scheme is an attempt of the engineers to put the nature in bondage for utilizing the natural resources to the services of the people of the land.

The main feature of the Mayurakshi Project is the construction of a reservoir by building a dam—2,107 ft. long and 113 ft. high—across the Mayurakshi at Massanjore in Bihar, where the river passes through a narrow gorge. The reservior which has a catchment area of 718 sq. miles, will over 27 sq. miles and store 5,00,000 acres ft. of water measuring 13,620 million gallons.

Irrigation is the main purpose of the Project though flood control and generation of hydro-electric power are its subsidiary benefits.

Planning

The power station situated in the middle of river at the foot of the dam may be said to have divided it into two parts and the western part has been fitted with all the spillway gates for discharging the surplus flood water. The irrigation water is drawn from the six undersluices—three high level and three low level—fitted on the other side.

The firm output of power is 2,000 kW throughout the year; the total installed capacity being 4,000 kW which could be generated during the monsoon. Two vertically mounted turbo-alternators in operation will generate electricity at 11,000 volts; the service voltage being 33,000 through double circuit transmission lines emanating from the main Outdoor Sub-station adjacent to the Power Station.

The Mayurakshi Grid has been connected with the DVC Grid to supplement the power generated at Massanjore.

Suri, the headquarters of Birbhum district has been chosen the load centre where the main distributing station has been erected. From this station the power is transmitted to the adjoining towns such as Dubrajpur, colliery areas of Pandaveswar, Mohammed bazar and Ahmedpur Community townships, Sainthia, Bolpur, Gushkara, Mollarpur, Rampurhat and Nalhati. The total transmission lines in the Mayurakshi Grid are about 100 miles.

The hydel power would mostly be utilized for the rural electrification schemes including Community Development Project in the Mayurakshi zone. The cheap electricity would no doubt assist in building up cottage and other small scale industries in the area. In the irrigation commanded area there are zones where 'Lift Irrigation' would be necessary and schemes are being worked out for such irrigation by electric power.

The electrical equipment including turbines, generators, switchgears etc. have been supplied by the Govt. of Canada under the Colombo Plan. The erection of the power plant and machinery started in October '55 and was completed in July, 1956.

A spirit of devotion to the service and excellent co-operation amongst the staff, prevailed all through the construction stages. The problems that cropped up during the progress of work were solved with mutual co-operation and consultation.

The Power House

The stone masonry building measures about 55′ ×71′ and is a two-storied one with a basement. It has its basement floor at EL 292 and its roof at EL 331. The turbines are located at the basement; the excitors governors, 11 kV switchgear and hydraulic panel and battery, tool stores are on ground floor. The control panel, engineers' room and office, lavatory are all on the first floor.

Turbine & Turbine Regulators

The turbines are of the francis reaction type with a nominal rating of 2,800 H.P. at 300 cubic ft. per second of water and a head of 90 ft. The speed is 428 r.p.m.

Generators

The generators are designed for 2500 kilo Volt-amperes at 11,000 V, at a power factor of 80% capable of delivering this rated output at any power factor from 70% to 100% and a speed of 375 revolutions per minute and to withstand continuously a runaway speed of 750 revolutions per minute.

The stator has a diamond winding and two circuit per phase arranged to permit splitphase relay pro-

tection of the generator. For transport purposes, the stator is made in two parts.

The rotor is equipped with non-continuous, low-resistance damping windings and is so designed that by the removal of one or more pole pieces a stator coil can be removed and replaced without further dismantling of the machine. The fieldwinding collector rings are located above the rotor and are easily accessible for clearing, repairing and removal. Insulation is class B.

The Generator has a lower combined thrust and guide bearing. The gearings are self-lubricating. The thrust bearing is capable of carrying the continued weight of the revolving portions of the generator, exciter, thrust bearing and turbine, together with the unbalanced hydraulic thrust of the turbine under all starting, running and stoppage conditions which may be encountered in operation. The cooling system is totally enclosed with coolers placed around the stator.

The generators are generously dimensioned in all respects and the transient reactance is of the "normal order" i.e.27%.

The short circuit ratio of the generator has a value between 1 and 1.12.

Generating Plant of the Mayurakshi Power Station

Transformers

The transformers step up the electric power from a nominal voltage of 11,000 volts to a nominal voltage of 34,500 volts at the generating stations and step down the power from a nominal voltage of 34,500 volts to a nominal voltage of 11,000 volts at various sub-stations on the system. Also step down some of the power from a nominal voltage of 11,000 volts to a nominal voltage of 400 or 420 volts at various places.

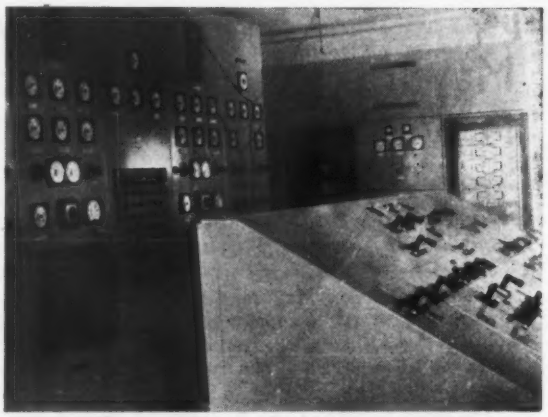
There are two transformers at the Massanjore Generating Station.

Capacity ..2,500 kVA, 3 phase, 50 cycles,

High Voltage windings ..34,500 volts phase to phase, with four 2.5% "off-load" ratio adjusting taps above the rated voltage,—wye connected, with a solidly grounded neutral,

Low Voltage windings ..11,000 volts, delta connected.

Each transformer is equipped with "on-load" remotely controlled, tap changing switchgear on the high-voltage side.



Control Room showing the Control Desk and Control Panel

The 11,000 volts transformers are equipped on the high voltage windings with two 2.5% 'off-load' ratio adjusting taps above the rated voltage and two 25% "off-load" ratio adjusting taps below the rated voltage, of full capacity delta connected low voltage windings : 400 volts wye connected, with a solidly grounded neutral.

The transformers are oil insulated and self-cooled.

The transformers having a normal voltage rating of 34,500 volts have a normal reactance of 6% based on their kilo volt-amperes ratings.

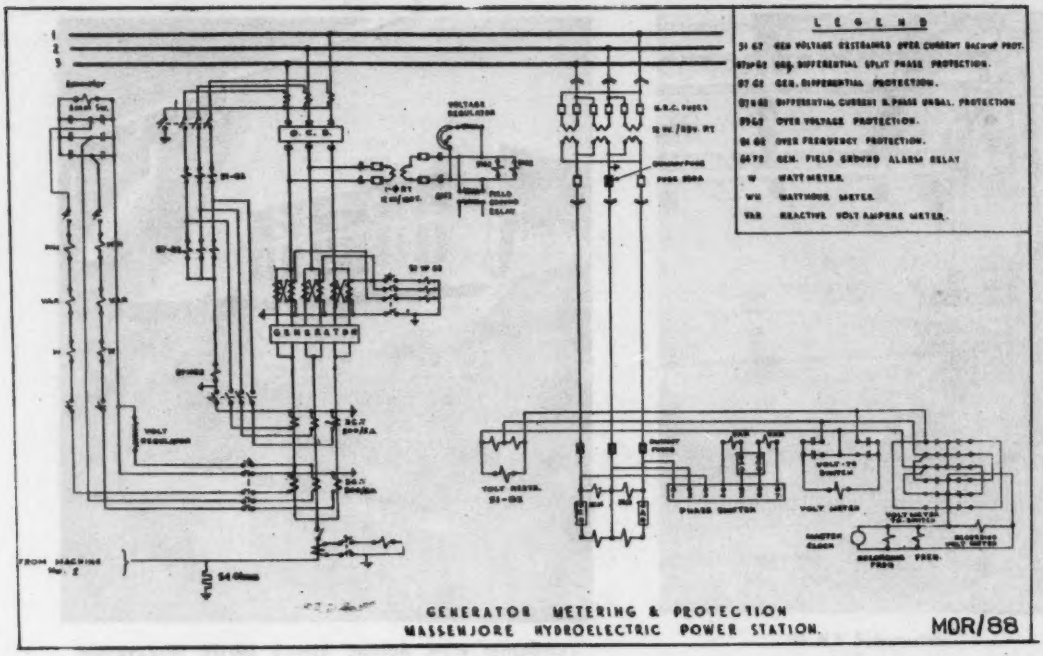
The Transformers having a normal voltage rating of 11,000 volts on their high-voltage windings have a normal reactance of 5% based on their kilo volt-amperes ratings.

The 34,500 volt bushings are of the procelain oil-filled type. They withstand an impulse test voltage minimum 2,50,000 crest value based on a 1.5×40 microsecond full wave. The 34,500 volt bushing are fitted with adjustable co-ordinating gaps. The spacing of the gaps are adjusted down to a minimum impulse breakdown voltage of 1,45,000 under standard dry conditions.

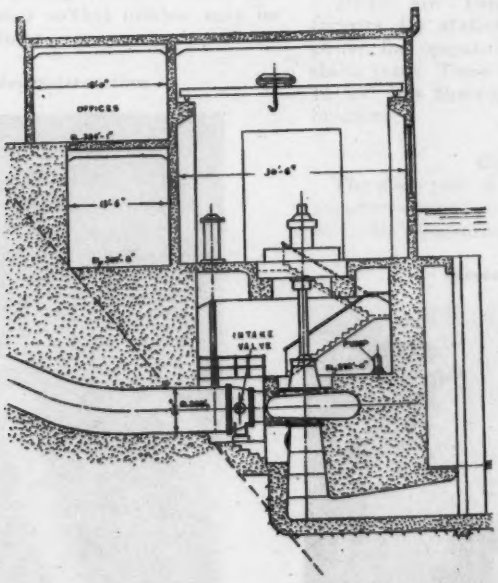
Outdoor Switchgear

The 34.5 Switchgear is built up from a double bus bar system and three phase voltage transformer sets in both bus bar system.

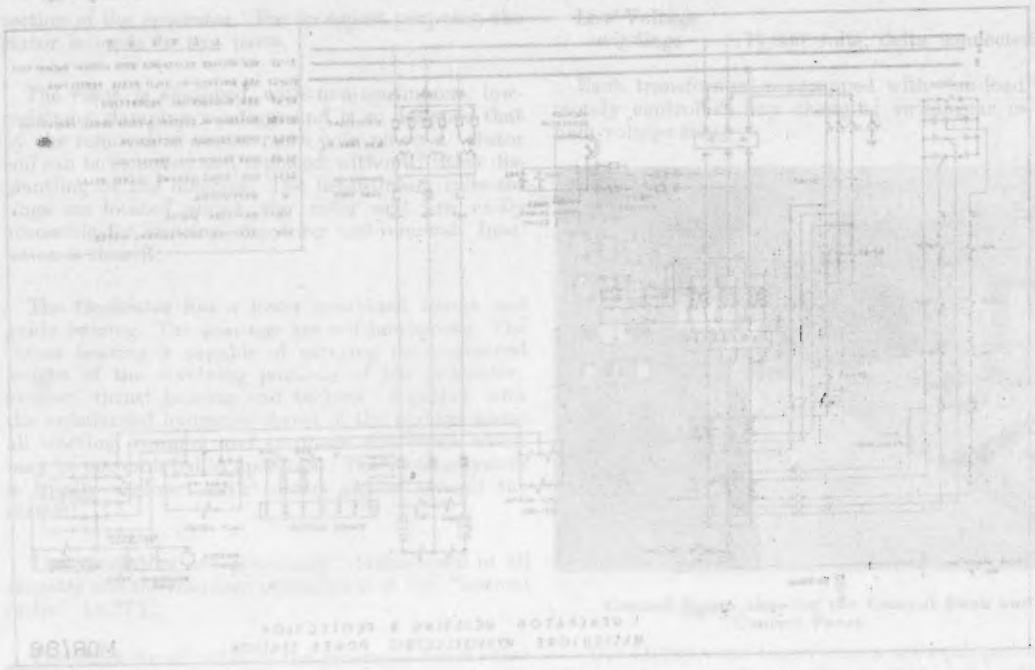
The Switching Station is built for a service voltage of 33 kV. The circuit breakers are of the bulk oil type and are suitable to be used with safety at 41,700 volts, capable of carrying not less than 600 amperes continuously and are capable of interrupting a fault current equal to 250,000 symmetrical runs kilo volt-amperes at 31,000 volts with the current wave completely displaced by a D.C. component. They withstand stresses which might result from closing on



GENERATOR METERING & PROTECTION
MASSENJORE HYDROELECTRIC POWER STATION. M0R/88



CROSS-SECTION THROUGH DAM AND POWER HOUSE

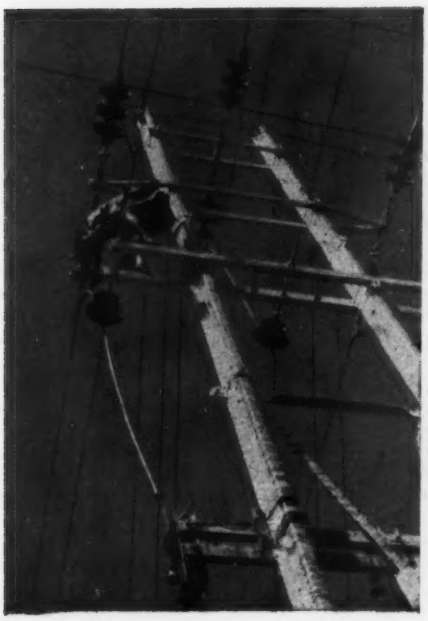


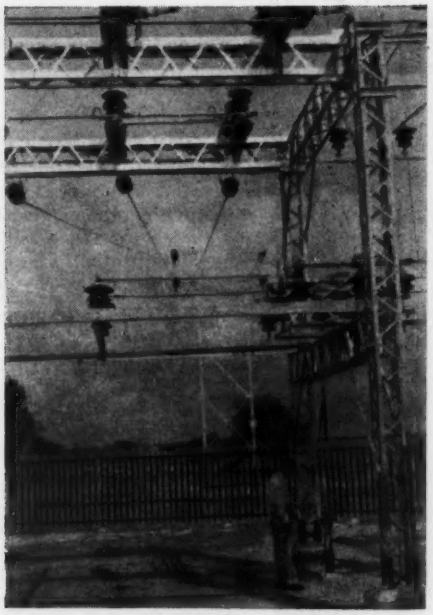
Mayurakshi Hydel Power Station with temporary water load arrangement

a fault which yield an instantaneous peak current of approximately 20,000 amperes.

The circuit breakers are equipped with key type mechanical interlocks which are arranged with similar interlocks on the disconnecting switches so that the disconnecting switches may not be operated while the circuit breakers are closed. The isolators nearest the lines have earthing switches which are interlocked with each other so that neither may be closed until the other is fully open.

H. T. line under construction





33 KV Substation

The potential transformers are rated to serve a burden of not less than 500 volt-amperes each, general description being : 500 VA, 34,500-115 volts, single phase, 50 cycles, oil-insulated, self-cooled.

Lighting Arresters have been fitted nearest to the line to give protection against surge voltages.

Station and Colony power supply

There are two 150 kVA, 11/0.4 kV transformers for station and colony supplies including power for operation of emergency and radial and sluice gates. These transformers are connected to the 11 kV bus through 11 kV, 250 mVA oil circuit breakers.

Control Equipment

The main part of the Station control, operating and protective equipment together with the equipment for kWh measurement occupies the largest part of

Street Lighting in a town

of the upper floor of the Power House. The actual control room has been planned for easy supervision. There are :

(1) Main control switchboard,

(2) Instrument and relay switchboard for the generators, transformers and 34,500 volt transmission lines,

(3) 11,000 volt switching equipment with instrument and relay panels for the station service transformers and radial feeders,

(4) Hydraulic instrument panels,

(5) Control battery, battery charger and Station service switchboard,

(6) Generator terminal cubicles, surge arrester equipments, neutral grounding resistors, field circuit breakers etc.

Rural Electrification, Sainthia

The indicating instruments and the relays are semi-flush type which makes it convenient for testing and setting in situ and could be withdrawn from cases for inspection and maintenance.

All control switches and auxiliary tripping relays are of the rotating shaft and cam type.. The main control switchboard is of the desk type provided with a single-line mimic bus bar system complete with control switches, mimic disconnecting and grounding switches, transmission line, distribution feeder, transformer and generator symbols. Lamp tableaux mounted in the desk contain an indicating lamp for each operation.

Protection

The protections provided are

(*a*) for each generator :
3—Voltage restrained overcurrent relays,
3—Differential current relays,
3—Split-phase differential current relays,
1—Neutral current relay,
1—Field ground alarm relay,
1—Overvoltage relay,
1—Over-frequency relay,
4—Bearing temp. relays.

(*b*) for each transformer bank :
3—Induction type overcurrent relays without instantaneous attachments,
3—Harmonic restrained current differential relays.

(*c*) for each 34,500 volt transmission circuit :
3—Induction type directional o.c. relays with instantaneous o.c. attachments.
1—Current biased directional induction residual current relay,
1—Induction type residual current relay.

For the complete station there is a bell alarm indicating panel which indicates clearly which unit or circuit is in trouble and also nature of the trouble.

There are alarm relays for the bearing temperature and oil pressure to indicate when the temperature or pressure has reached the danger point.

The power for the control, signal, alarm and miscellaneous uses on the switchboard is obtained from the following sources. :

125 Volts, D. C. from battery.
242 Volts, single phase, A.C., 50 cycles.
420 Volts, three phase, 50 cycles.

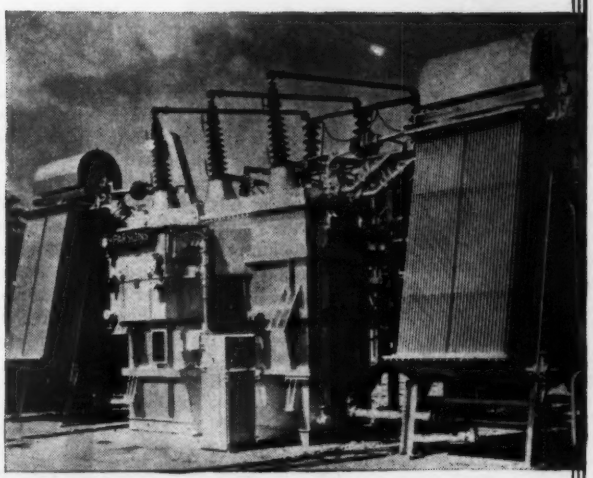
The power from the Station was formally switched on by Sir D. N. Mitra on the 16th of December, 1956 and all the towns and the coal-field area in the Mayurakshi Scheme are now being supplied from the Mayurakshi Electric Grid. The concept of the multipurpose development of river valleys has now taken root in this country. In the past hardly have the waters of a river been treated in a unified manner so as to promote a multi-facet co-ordinated development of the entire valley through which it flows. After the successful experiment by the Tennessee Valley Authority in America, it has been recognised all over the world that it is far more rational and economic to handle a river in all the aspects in relation to the resources and the needs of the river valley concerned. The power development has led to a phenomenal progress in industries in the valley utilising its natural resources. In Bengal a couple of schemes are in hand for the generation of hydel-power and investigations are in progress for harnessing the turbulent river Teesta in North Bengal which would yield about 400 megawatts.

C. A. PARSONS

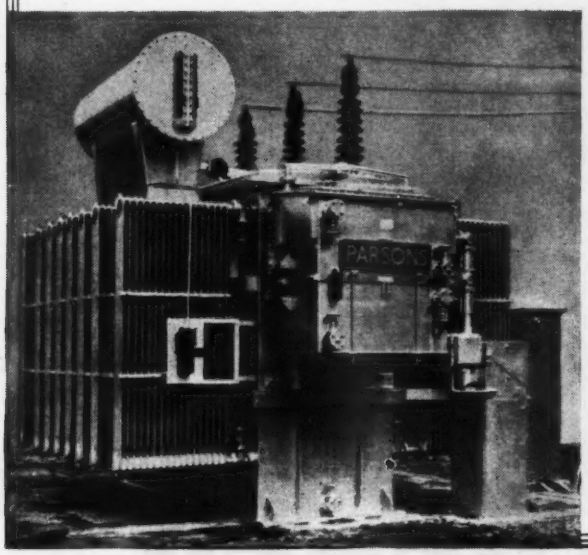
Power

and

Distribution



TRANSFORMERS



The illustrations show two types of transformers, both fitted with on load tap changing gear.

Agents in India

MARTIN BURN LTD.

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First Harvest
Since he first probed the secrets of the atom, man has pursued the vision of using its enormous forces for practical power production. Ideas in the minds of scientist and engineer were the seeds that have now come to fruition with the opening of Calder Hall, the world's first full-scale atomic power station. The contribution of Babcock & Wilcox Ltd. to this remarkable achievement started eight years ago when, at the request of the Government, they undertook the design study of steam-raising plant for nuclear power stations. They have since manufactured and installed all the special 80-feet-high steam-generating towers for Calder Hall and are extensively engaged in other important developments which offer to the nation a sure promise of greater harvests in the field of atomic power.

BABCOCK

BABCOCK & WILCOX OF INDIA (PRIVATE) LIMITED. CALCUTTA & BOMBAY

Nuclear Power Generation

By Dr. M. DUTTA *Ph.D.(Edin). M.Sc.(Tech.) (Manch.) M.Sc., M.I.E.E. (Lond.), Superintending Engineer (Headquarters), W. Bengal State Electricity Board* and R. N. GANGULY, *Divisional Engineer (Testing)*

The basic nuclear fuels are uranium and thorium. It is well known that among the reactor fuels for the fission release of energy, Uranium $_{235}$ is the primary fuel which is obtainable naturally with a concentration of 0.71% with U_{238}. U_{233} and Pu_{239} are fissionable isotopes which can be formed artificially by neutron irradiation of thorium and uranium.

Indian west coast is famous for its well known deposits of monazite sands. Plants are now producing cakes containing uranium and thorium.

Nuclear energy is released either by fission or fusion of heavy or light nuclear respectively. Whenever a a heavy nucleus is split into two nuclei or when two light nuclei are fused into a single heavy nucleus there is a loss of mass which appears as energy as given by Einstein's well known equation (relation given by) $E=mC^2$ where m is the lost mass and C is the velocity of light. Fusion can only take place where temperature is extremely high whereas fissionable fuel is not easily available.

When a nucleus of U_{235} in the natural uranium fuel is struck by a thermal neutron it undergoes fission. Surplus neutrons are released whose number is nearly 2.5 per fission. The fission is also accompanied by release of heat energy. This heat energy is utilised for the production of electrical energy. (Fig. 1)

At least one out of 2.5 neutrons must be available for further bombardment of U_{235}. If it is less than one, the chain reaction dies out.

U_{238} is not fissionable by thermal neutron but it absorbs neutron and ultimately forms Pu_{235} a stable isotope.

Similarly when Th_{232} absorbs neutron we have the following reaction.

$$Th^{232} + n \longrightarrow Th^{233} \xrightarrow{\beta} Pa^{233} \xrightarrow{\beta,\gamma} U^{233}\ \text{(Stable-Isotope)}$$

(Proto-actinium)

Fig. 2

The stable isotopes Pu_{239} or Th_{233} are fissionable if sufficient neutrons are available. Pu_{239} may prove in future to be better fuel than U_{235} and may be used in fast fission reactor at a future date when it could be extracted chemically. Neutron release of Pu_{239} is nearly 3 per fission as against 2.5 of U_{235}.

In nuclear fuels complete burn up of the fuel cannot be accomplished for (*a*) depletion of fissile material and progressive build up of $Xenon_{135}$ and $Samarium_{149}$ which are important fission product poison having very high thermal neutron capture cross section. (*b*) dimensional changes in the fuel element due to growth and swelling.

The fuel element is to be periodically removed for chemical processing. (Fig. 3)

Design of Reactor

It is rightly said that building up nuclear power-station is like building of a military aircraft. The technological progress is so rapid that the best design of to-day may become obsolete in few years' time. A rapid improvement is necessary towards atomic-physical aspect of the design of reactor which involves several problems such as efficient design of critical system, suitable control for the level of power release, profitable use of neutron for production of fissile material and dependable safety devices for personnel from harmful radiation.

Reactors may be broadly classified into two groups.

(*a*) Thermal reactor (*b*) Fast Fission Reactor.

Thermal Reactor

The name thermal is attributed because the velocity of the bombarding neutron is lowered to thermal energies.

The design of a reactor is greatly influenced by (1) Moderator (2) Coolant (3) Nature of fuel. The function of a moderator is to slow down the speed of neutron so that their chances of coming in contact with U_{235} is increased whereas the probability of its being absorbed by U_{238} is decreased. Hence the natural uranium ore is to be placed in descrete lumps in the moderator for the chain reaction to sustain. The criteria for the choice of moderator is that atomic weight should be small and that its neutron capture co-efficient should be as small as possible, otherwise most of neutrons released during fission will be absorbed by moderator and hence the chain reaction may die out. Graphite, Heavy water, Light water and Beryllium could be used as moderator.

The function of coolant is to remove the heat produced in Reactor. The performance must be economical and heat transfer must be efficient. The coolant must have low neutron capture cross-section as the reactor may turn supercritical if coolant circuit fails. Heavy water, Light water, CO_2 could be used for coolant.

For every thermal reactor there is a critical size. A reactor smaller than critical size is unable to maintain the chain reaction.

There are several possibilities with regard to the types of reactor. Some are discussed here.

(*i*) *Graphite moderated CO_2 cooled reactor:*
This type of reactor is going to be built at Berkley in Gloucestershire, U.K. Graphite has a low thermal neutron cross section nearly .0045 barn (1barn=A cross section of 10^{-24} cm² per nucleus).

In India attempt is being made to obtain atomically pure graphite from the coke produced in the refineries of Assam.

The coolant gas circulators are of axial flow type and driven by squirrel cage motor with the arrangement for variable speed coupling. The power demand of the blowers are heavy.

The Reactor core are generally about 40′ diameter. The temperature of gas outlet is 350°C and pressure 100 lb/sq. in. The hot gas gives up its heat to preheating, evaporating and superheating sections of steam plants. After passing through the steam raising towers the gas is recirculated. Each steam raising tower is provided with two separate steam raising arrangement i.e., H.P. and L.P. sections. The turbines are of special design for obtaining maximum efficiency from comparatively low temperature, hence a double pressure steam cycle is used. Live steam enters the turbine at two points. L.P. section will receive live steam direct as well as the steam from H.P. section after being expanded.

This type of reactor not only produces power but also Plutonium. It uses natural uranium. (Fig. 4&5).

(*ii*) *Heavy water moderated and heavy water cooled reactor:*
Heavy water as moderator appears to be more prospective than graphite. It has low neutron capture cross section given by .00092 Barns. The greatest deterrent with regard to its use was its high cost. India has decided to produce heavy water in all her fertiliser factories in the 2nd Five Year Plan.

In this type of reactor the diameter of core could be reduced to 10/12 ft. The temperature of coolant should not be more than 242°C assuming a pressure of 500 lb./sq.inch.* With liquid coolant a great advantage is that a higher rate of circulation is possible.

In order to better the thermal efficiency higher temperature and pressure should be used for driving the turbines. The lower steam conditions demand a greater flow of steam which again brings forth some unusual problems for the exhaust. Moreover, as previously discussed, if turbines are designed to utilise steam at two different pressures an elaborate arrangement will be necessary for governing gears.

* Boiling must be prevented in Reactor.

To avoid these difficulties, the best proposition would be to raise the condition of steam by a separately fired superheater. (Fig. 6).

(*iii*) *Light-water moderator and light water coolant:*
This type of reactor should have to be operated in conjunction with a separately fired superheater. The greatest advantage of light water is the freedom and ease with which it could be used. Enriched uranium is to be used as the moderator has a comparatively high neutron capture cross section. The diameter of Reactor could be substantially reduced.

Beryllium oxide moderated Reactor

India has a very large deposit of rare mineral beryl from which beryllium could be extracted. Beryllium and Zirconium refining plant is going to be set up in India. Beryllium oxide has a good prospect for use as moderator.

Fast Fission Reactor or Breeder Reactor

In Fast Fission Reactor the use of moderator is dispensed with. This type of reactor will be using U_{233} or U_{235} or Pu_{239}. This type of reactor can breed more plutonium than it consumes U_{235} since the core of reactor may be surrounded by natural uranium which may capture neutron and produce plutonium.

The greatest difficulty which is confronted with regard to the design of this type of reactor is how to transfer tremendous heat energy that is released during fission. By using 1 kg. of U_{235} about 22,000 mWh of heat is released. The core of this type of reactor is small. Hence it is absolutely necessary to use mercury or sodium, or potassium as liquid coolant for the transference of heat. Every attempt is being made for an efficient design of liquid metal pumps.

In future a breeder reactor will have a scope for the use as mobile power unit. It may be used for producing stable isotopes though it is expected that plutonium could be extracted chemically in the near future.

Structural material

The reactors should be encased in reinforced concrete having suitable quality to withstand both radiation and pressure. Thick concrete can effectively stop γ-ray radiation. The innerside of the concrete may be covered with steel plates to stop neutron absorption of concrete.

British Atomic Energy Establishment remarked "Many of most urgent of our unsolved problems lie in the field of metallurgy." Extensive metallurgical research is necessary with regard to the effect of radiation on metals with particular reference to elasticity, creep, corrosion, resistance. One of the major consideration in the choice of a structural material is that the material must have low thermal neutron capture cross section. Zirconium, Beryllium, Magnesium and Aluminium are found to be suitable. Magnesium-Zirconium alloys, though having a comparatively low melting point, could be satisfactiorily used. At present aluminium is extensively used in reactor for economic reason. Ferritic and Austentic stainless steels are capable of withstanding very high pressure and temperature (8000 lb./sq.in. and 700°C). Radiation effect on these steel should be properly investiga-

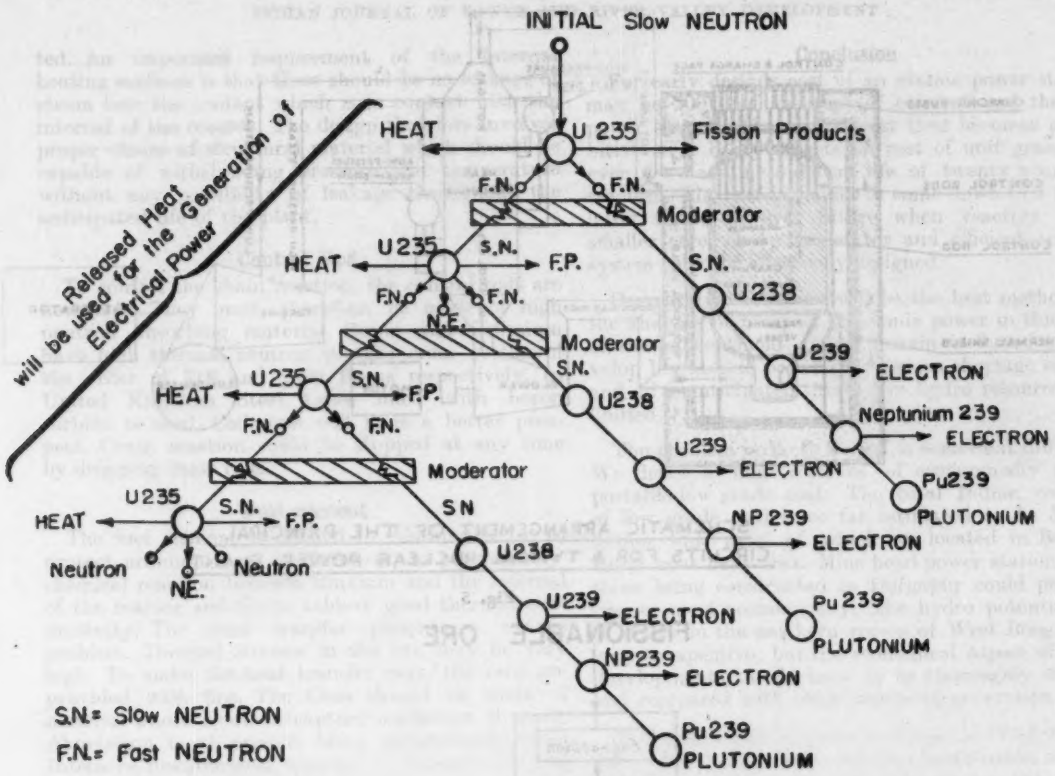
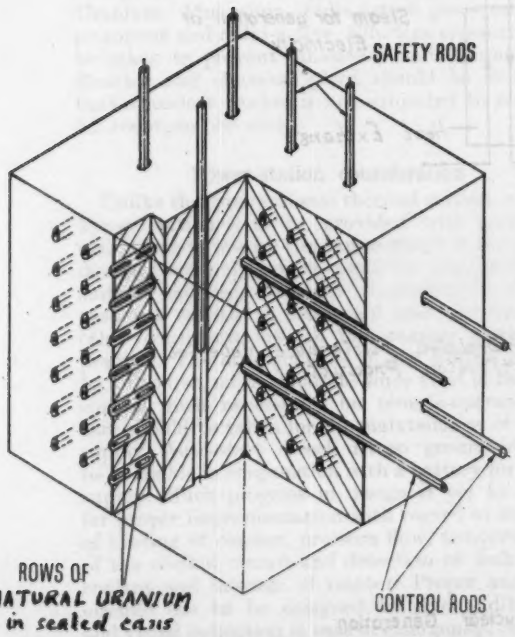


Fig.1 Diagram display of Chain Reaction.



Schematic cutaway view to show the basic principles at a Uranium Graphite Reactor. The reactor is controlled by Cadmium steel rods. Similar vertical rods will operate under gravitational pull in emergency.

Fig. 4

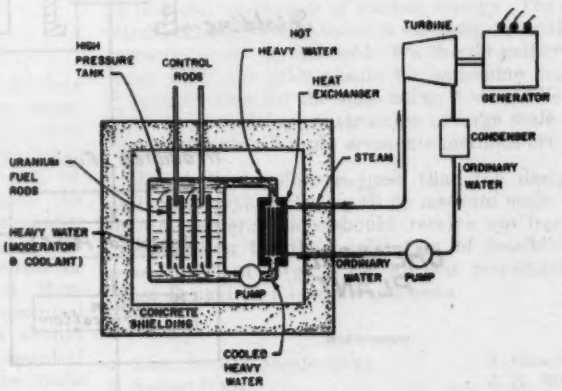
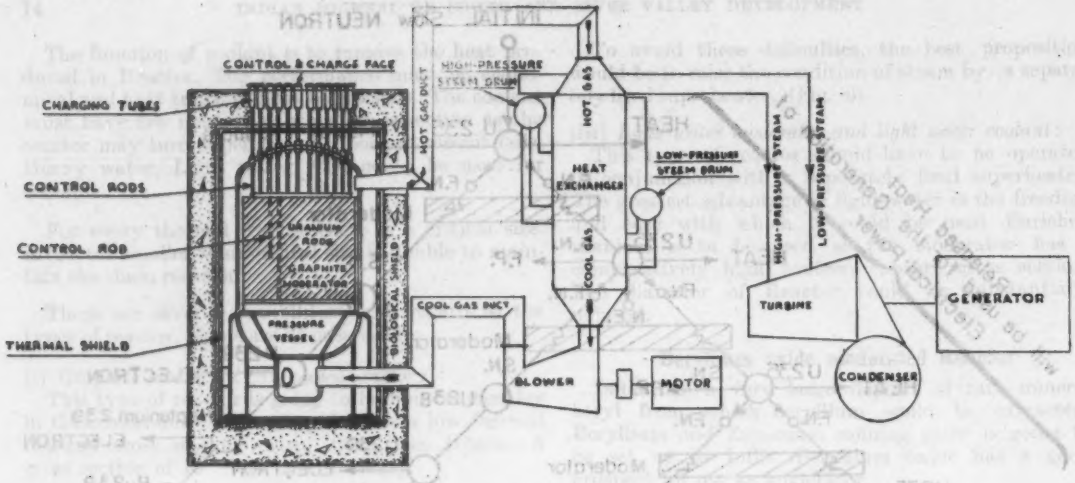


Fig. 6



SCHEMATIC ARRANGEMENT OF THE PRINCIPAL CIRCUITS FOR A TYPICAL NUCLEAR POWER PLANT

Fig. 5

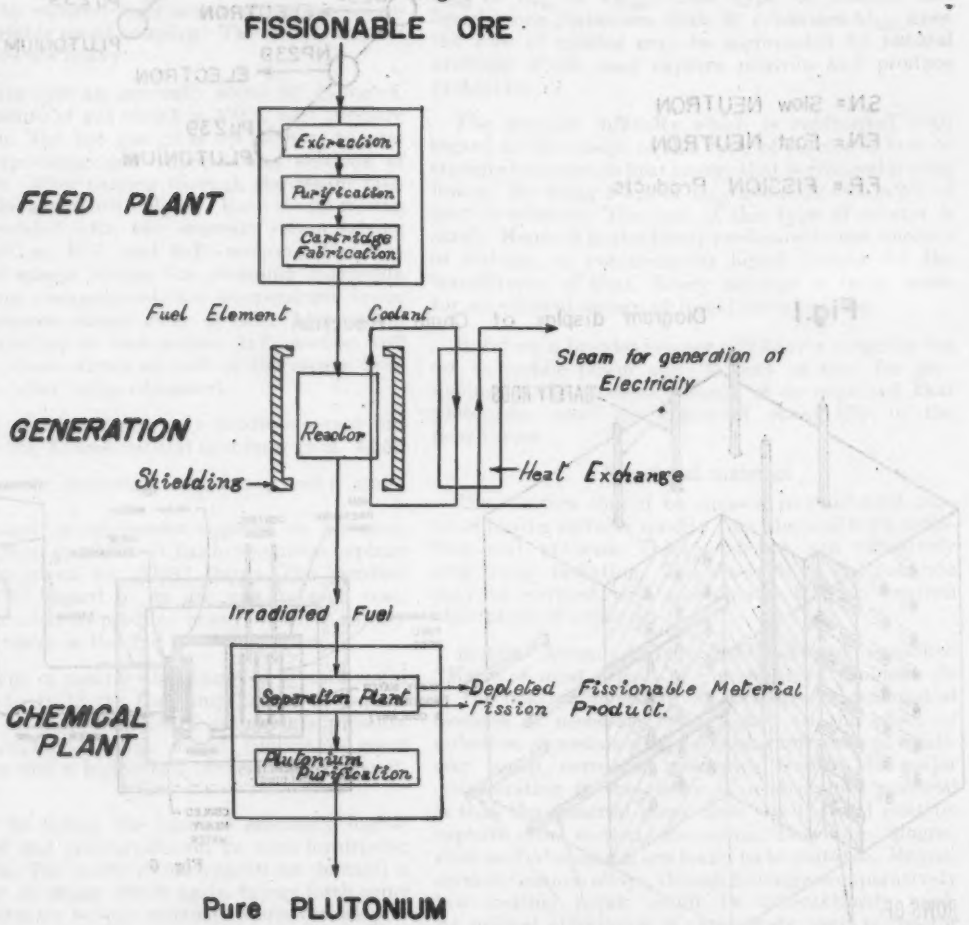


Fig.3 Basic idea of the Problems of Nuclear Generation

ted. An important requirement of the internal heating surfaces is that there should be no leakage of steam into the coolant which is in contact with the internal of the reactor. The design therefore involves proper choice of structural material which should be capable of withstanding pressure and temperature without any possibility of leakage throughout the anticipated life of the plant.

Control Rod

To control the chain reaction, the control rods are necessary. They must, therefore, be made of high neutron absorbing material. Boron and Cadmium have high thermal neutron capture cross section of the order of 718 and 2500 Barns respectively. In United Kingdom Steel tubes filled with boron carbide is used. Cadmium will have a better prospect. Chain reaction could be stopped at any time by dropping these rods.

Fuel element

The fuel element is canned in Aluminium (*a*) to protect uranium from oxidation (*b*) to prevent any chemical reaction between uranium and the internal of the reactor and (*c*) to achieve good thermal conductivity. The heat transfer presents a serious problem. Thermal stresses in the can may be very high. To make the heat transfer easy, the cans are provided with fins. The Cans should be made of material whose Neutron capture coefficient is small. Aluminium is at present being satisfactorily used. Intensive metallurgical research is necessary to find properties of different materials under heavy neutron bombardment.

Provision should be made for the removal of spent fuel. It is chemically processed by remote control operation when isotopes are extracted and wastes are discharged into the sea. Many substances that are produced during chemical processes including Uranium, Plutonium, radio-active gases are highly poisonous and radio-active. Effective measures should be taken to prevent inhalation and contamination. Reactor and chemical plant should be so screened that a nuclear worker is not subjected to more than 0.3 roentgen per week.

Power-station consideration

Unlike the conventional thermal station, a Nuclear Power station is to be provided with dump steam condensers to absorb the excess steam if the electrical demand suddenly lowers, until the reactor output is suitably reduced. Two sets of alternators should be used per reactor to efficiently load the reactor. All other considerations are like normal power-station practice. The arrangements in the control room will be, of course, more elaborate since most of the reactor control must necessarily be remote-operated. More care should be taken for the maintenance of essential supply. Auto-start diesel driven generators should be available in conjunction with a battery for essential supply. Much progress in design is yet to be made for proper instrumentation with regard to indications of loading of reactor, pressure flow, temperature etc. of the coolant circuit and detection of leak between coolant and internal of reactor. Proper annunciator circuits are be be designed to give audible alarm and visual indication in case of emergency. Automatic protection must be there to protect the reactor in dangerous condition.

Conclusion

For early designs cost of an atomic power station may be 200% of the cost of conventional thermal power station. The capital cost thus becomes prohibitive as it badly reflects on cost of unit generated even if we assume a decent life of twenty years for reactors. The cost is bound to come down to a much lower figure in near future when reactors with smaller core, cheap moderator and efficient coolant system could be effectively designed.

Comparative economy will be the best method for the analysis of prospect of atomic power in this part of the subcontinent. Great Britain is forced to develop her atomic power as a serious shortage of coal and oil is anticipated there. Her hydro resources are limited.

The problem in West Bengal is somewhat different. We have a huge reserves of economically transportable low grade coal. The total Indian reserves of low grade coal is so far estimated to be 39,000 million tons most of which are located in Bengal-Bihar coal field area. Mine head power stations like those being constructed in Durgapur could produce power most economically. The hydro potentialities of rivers in the northern region of West Bengal are very prospective, but the economical aspect of their developments should have to be thoroughly studied and compared with other modes of generation.

The steady rate of growth of load in West Bengal since World War II necessitates installation of new generating plants. Several problems are yet to be solved before West Bengal could venture to consstruct nuclear power station. To operate nuclear power station economically and efficiently it has to be operated at highest possible load factor. We have to make our grid and inter-connectors more extensive and flexible. Our protective and metering equipment should be so designed that these could maintain stability, selectivity and sensitivity in the event of quick transfer of load.

We should not lag behind other countries and nor should we lose ground in the modern world with regard to peaceful utilisation of nuclear energy. The Indian Atomic Energy Commission is carrying out extensive research work in this field. We should gather knowledge from our pilot plants for sometime more but it appears that for the time being it would be advisable for us to delay construction of large scale atomic power stations till more economic methods are found.

We shall therefore suggest that the design and and construction of a small or medium scale experimental power station should receive our immediate consideration for the exploration of feasibility and possibilities of large scale nuclear powerstation in West Bengal on a commercial basis.

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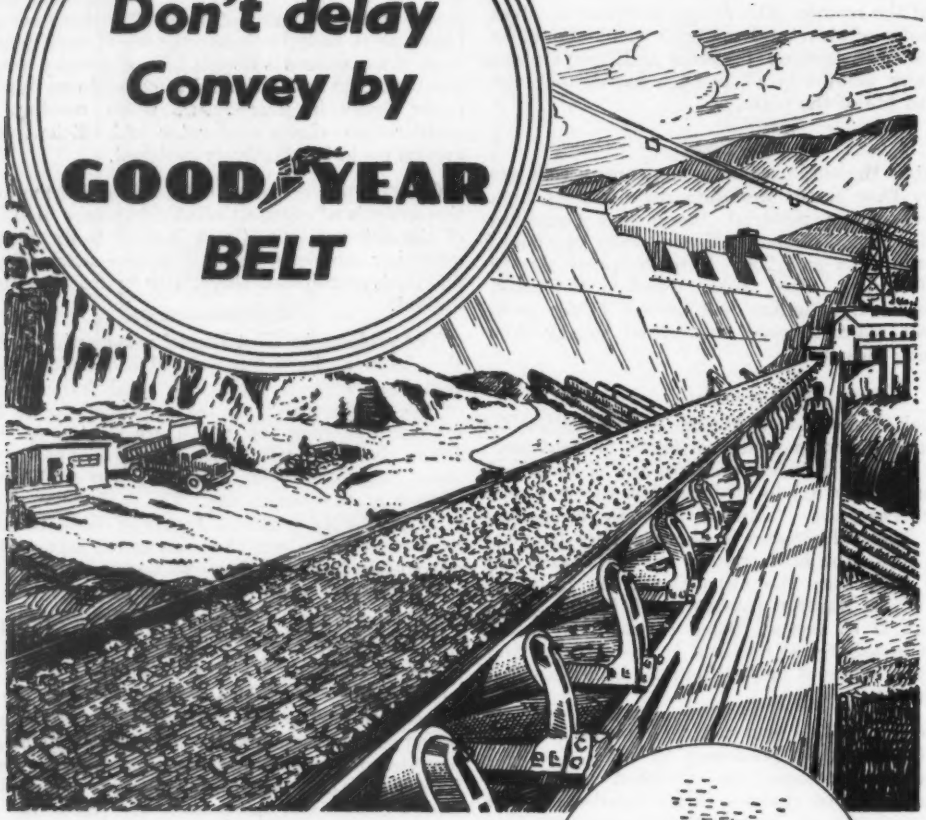

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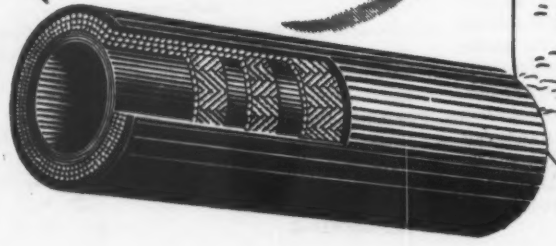

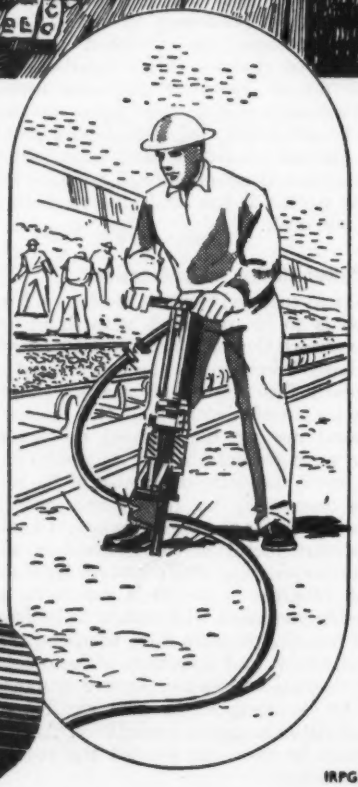

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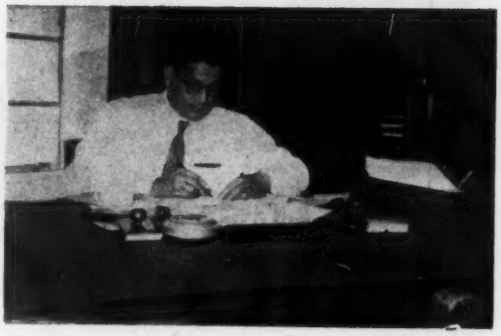
Textile Machinery Industry at Kalyani



By M. P. GHOSE, B.E., A.M.I.E.
Superintending Engineer, (North), West Bengal State Electricity Board

Kalyani, apparently built for the purpose of relieving Calcutta where density of population is, perhaps, highest in the world, has but poor response so far in spite of its better housing, and hygienic and other amenities. The cause of this reluctance of permanent settlers and immigrants to leave Calcutta can, however, be traced to the absence of a high industrial structure in and around this town which can solve the problem of unemployment and rehabilitation, and ease the pressure on Calcutta. The onus of raising the structure, of course, lies mainly on the Government which, with the modest start of one or two factories, has perhaps, so far, shown the cautious approach of an explorer. This is all the more welcome.

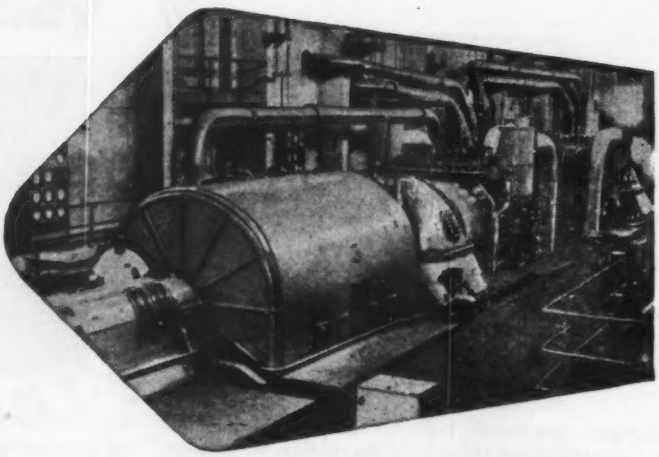
But, inspite of the very best intentions, a high industrial structure with a heavy industry as its very core has not been a reality. The things that tip the scale of one's preference for one locality to another for the setting up of an industry will be the better advantages of the former in respect of labour and transport costs. Kalyani, at a distance of 32 miles from Calcutta, has little headache for labour costs, but it does not answer well to the principle of minimum cost in so far as transport (i.e., in respect of getting raw materials supply, and making finished goods reach the market) is concerned. The sources of raw materials, such as coal and steel, are distant from Kalyani. Situated in the farthest corner of India, far from her western and southern reaches, Kalyani's industries will have to face the problem of proper domestic prices for their products, since the problem becomes more difficult as the distance becomes greater. Such matters are highly important, even though relative nearness to the Port of Calcutta creates not too bad an impression in favour of Kalyani (as against any other inland centre) for the establishment of an industry with export bias. Heavy industry, moreover, is a heavy burden on an underdeveloped economy and there must be a dead line for costs, which must be kept in sight while choosing a site. The above must have weighed with Government in deciding not to usher in a full scale high type industrial programme at Kalyani immediately.

But for some time the Government of India has been broadening its perspectives for the distribution and control of industries throughout India. The result is equalisation of steel price which is expected to be followed by an equalisation of coal rate chargeable to all consumers alike wherever located. Thus, measures are being taken for breaking down cost barriers and regional distribution of industries with equalization of life in different localities. This is opening new vistas.

It has already been mentioned before that the onus of setting up an industrial structure at Kalyani lies on the Government. The onus is also with respect to the right type of industry. We are giving way to Japan and other new entrants in the Asian market for textiles. Japan is scoring points over us because of automatisation of the cotton mills working with imported cotton. By replacing three thousand ordinary looms by automatic looms, we may check Japan's advance, though not outstrip her. Further cheapening of cost can be obtained in textile prices by standardising prices of raw cotton produced in India. Replacement and new investment in this field can be made possible, if an export bias is allowed to it. Conditions are also favourable for its catering for internal market.

To make all these happen, Kalyani may be a possible site for a heavy cotton textiles machinery industry turning out automatic looms. We have already talked on the advantages of relative nearness to port in respect of Kalyani in comparision with other inland centres. Introduction of automatization into the machinery industry itself will reduce its labour and operating cost much and raise its output which will be in heavy demand amongst the industrialists. This industry may also cater for markets in the far east. Intensive utilisation of road, rail, and sea communication and better co-ordination of such transports will put cost of inland transport down. In the wake of this, cotton mills will spring up in and around Kalyani. An industrial advance consequently will follow in other fields also to which concessional rates of land, lower railway rates, cash subsidies, cheap credits and other allurements may be given. In respect of electric power, all these means higher load demands and hence cheapening of its price and increase of its utility to the consumer. Finally, small scale and cottage industries will also come in to take advantage of this favourable scene and, all these industries being labour-intensive, there will be created a high level of employment and consequent settlement of population.

Power for the Millions by



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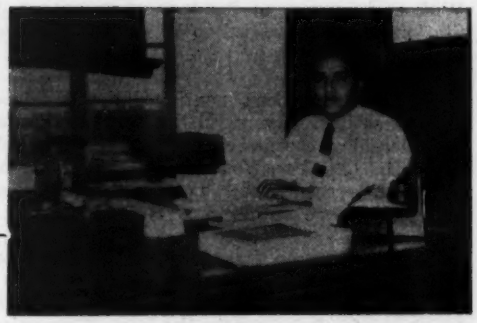
Jaldhaka Hydro-Electric Project: Effects of Investigation & Survey on Design Features



By B. N. CHOWDHURY, B.Sc., B.E., A.M.I.E.
Divisional Engineer (Hydro), West Bengal State Electricity Board

West Bengal, though it claims to be a pioneer in hydro-electric installation in India, had no worth-mentioning hydel installation of its own till the First Five Year Plan. This State, in its northern terrritory, has a number of hilly rivers with enormous power potentialities, suitable for taking up as commercial venture. Besides the above, seasonal power of monsoon discharge has also its ready market in the local tea industries—a remarkable feature not usually found in other hydro-electric projects. Inspite of such natural advantages, practically nothing had so far been done either due to lack of initiative or finance.

Out of the notable rivers of the area e.g. Teesta, Jaldhaka, Great Rangit, Jainti, Katulum and Raidhak, the river Jaldhaka drew the attention of various authorities for long time past. As far back as 1918 some of the local tea planters surveyed the river for generating cheap hydro-electric power for tea driers. Darjeeling Municipality also did some reconnoitring survey with a view to import such power to its own area. Later the State Government took up the systematic survey of the river, as one of their post-war development projects as well as to feed construction power to the Teesta Valley Project, a much pursued and favoured scheme of the then Government of Bengal. A firm of Consulting Engineers of Switzerland, at the request of the State Government, surveyed some important rivers of North Bengal and recommended earlier harnessing the Jaldhaka river in stages leaving other rivers for future development.

West Bengal State Electricity Board, after intensive survey of the entire river course, prepared a detailed report on Jaldhaka hydro-electric scheme and decided to implement the same during the Second Five Year Plan. To start with, the Board proposes to harness the river at its upper reaches and would progressively utilize the entire course as and when the load condition of the area so warrants. The scheme thus prepared by the State Electricity Board has since been approved by the Planning Commission for its immediate implementation.

Firm output of a hydel station can be determined by three different ways e.g.,

(*i*) *Total Storage*
Storing the entire discharge (except flood discharge) into a natural reservoir formed by building a high dam and controlled release of such water according to requirement.

(*ii*) *Semi-Storage*
Run-of-river discharge supplemented by storage of daily or weekly surplus water for use during peak hours of the Station.

(*iii*) *Run-of-river flow.*
Firm output of the Station is based on minimum discharge of the river during the year with negligible storage for hourly variation of load.

Due to steep slope of Jaldhaka river, silt contents of monsoon flow, and precipitous nature of soil, implementation of the first two methods are not economically feasible. The only course left is to build a short weir for intake of the perennial discharge and to carry it by a 'flume' along the contour of the hill to a suitable site as 'forebay' and then to the power-station by penstock.

To achieve maximum power output in such a scheme, it is desirable that the intake arrangement should be located as near to the last notable tributary of the main river as possible and the flume should be lengthened to the maximum economical limit as the geographical condition of the area permits.

In a run-of-river project like Jaldhaka, accurate determination of minimum discharge is essential for assessing the firm capacity of the generating station. From hydrological investigation of the last few years, it is evident that, minimum discharge of Jaldhaka river is about 250 cusecs, though in rare occasions it comes down to the level of 240. With the available gross 'head' of 640 ft., the said discharge corresponds to the firm average output of 10,000 kW or 17,000 kW at 60% load factor, expected to be achieved at full development. From the present statistics of electricity undertakings in the area the nature of ultimate load curve in the Jaldhaka project has been manipulated and is shown in Fig. 1.

Effect of daily storage of surplus water for increased output is also shown therein. Increasing the Station capacity of 17 mW. calls for storage provision of 6.0 m. cft. Economics of creating such a reservoir in the existing terrain is under study. Advantage of an existing terrace at Gourigong was taken for building

a supplementary reservoir for increased output. According to the detailed contour survey, the capacity of such reservoir can economically be raised to 1 m.cft. With such storage at hand, the firm output of the Station can be increased to 12,000 kW. corresponding to the peak discharge of 300 cusecs.

It has already been mentioned that the monsoon power has its ready market in local tea industries. Considerable power is being used in tea driers during 8 months (April to November) in the year. Nature of such power requirement and the power potentialities of the monsoon discharge is shown in Fig. 2.

It would be seen from such curves that economic utilisation of monsoon discharge over 300 cusecs is not possible in case such power is to be supplied to the tea driers for 8 months in the year. The entire project is therefore designed with the maximum discharge of 600 cusecs and for maximum output of 24,000 kW.

The project site is situated in the district of Darjeeling and at the boundary of India and Bhutan. The nearest railway station 'Chalsa' of the North Eastern Railway located adjacent to the Siliguri-Cooch Behar national highway is about 20 miles from the proposed generating station and 45 miles from Siliguri. The town of Siliguri is situated at a distance of 400 miles by road, 370 miles by rail and 276 miles by air from the city of Calcutta. Topographical layout of the project site showing the access road, intake dam, flume route, forebay, power house etc. are shown in Fig. 3.

The project envisages harnessing the river Jaldhaka by building a short 'weir' type dam across the river near the confluence of Bindukhola and Jaldhaka at an elevation of 1,880 R.L. The water is to be conveyed by one, 29,000 ft. long 700-cusecs capacity flume, to a forebay of 0.45 million cubic ft. capacity at the extreme end of Paren terrace at an elevation of 1,820 R.L. Two 2,500 ft. pipe lines of $5\frac{1}{2}$ ft. diameter would then carry the water to the power station for generating 24,000 kW of power at 0.80 power factor. The power station would be located near to the bank of Jaldhaka river at an elevation of 1,210 R.L. on the terrace situated at the confluence of Jaldhaka and Jhalungkhola.

It is proposed to instal 2 vertical turbo-generator sets of 17,000 H.P./12,000 kW. with 20% overload capacity each. For economy, no standby set is proposed in the Jaldhaka project. During initial years of low system load, one set would be sufficient for town electrification as well as tea drying while the other would be kept as standby. In later years of full development, the second set would run only during monsoon period to supply power to tea driers. It is expected that by such time the second stage of Jaldhaka project would successfully be implemented and such power be used as standby source during emergency or breakdown of any unit of the present Station.

Power will be generated at 11 kV., 50 cycles and through the station busbar it will be supplied to two three-phase 15,000 kVA 11/66 kV. step-up transformers at the adjoining switch-yard. Route diagram of the transmission lines to various parts of the area is shown in Fig. 4.

For proper control of load and maintenance of adequate power supply to various consumers in the project area, the Jaldhaka generating station would be interconnected with five other local generating systems in the near future. Details of such power supply systems are stated below : (see Table)

The site of the intake dam has provisionally been selected subject to various rock boring tests by Geological experts. The proposed dam would be of stone masonry concrete type with under-sluice gates for silt discharge. The dam would be of 15 ft. high and 200 ft. long and be built across the river at about 1,000 ft. downstream from the confluence of Bindukhola & Jaldhaka river. The dam when completed would form an intake pool of about 60,000 sq. ft. surface area and 0.50 m.cft. storage capacity. Such intake pool would be necessary for maintaining steady flow of water into the flume and to act as first settling tank. Near the confluence both the Jaldhaka & Bindukhola would be so trained as to enable the monsoon discharge to byepass through an adjacent old river, minimising thereby the effect of its direct onrush to the intake pool. Intake to the flume would be provided with trash racks and manually operated control gates. Final design of the dam has not yet been completed.

	Owner	*Nature of generation*	*Capacity*	*Gen. Voltage kV.*
(*i*) *Balasun Hydel Project	State Elec. Board.	Hydro	2×2500 kW.	11 kV.
(*ii*) Siliguri Diesel Station	-do-	Diesel	3×300 kW.	400 kV.
(*iii*) *Darjeeling Elec. Supply	Municipality	Hydro	5×200 kW 2×480 kW.	Grid Voltage 3.3 kV.
		Diesel	1 - 200 kW. 1 - 187 kW. 1 - 293 kW.	
(*iv*) **Mungpu Hydel Project.	Govt. of West Bengal	Hydro	2×750 kW.	11 kV.

*To be commissioned by 1960/61
**Still in schematic stage.

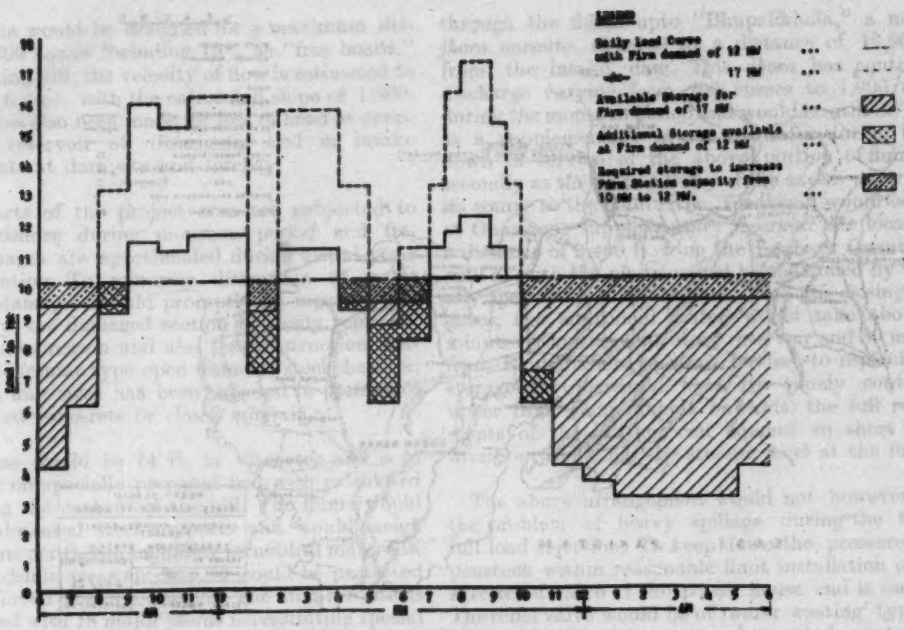

Daily load Curve with Firm demand of 12 MW
" " " 17 MW
Available Storage for Firm demand of 17 MW
Additional Storage available at Firm demand of 12 MW
Required storage to increase Firm Station capacity from 10 MW to 12 MW.
Load in MW
AM
NN
PM

Fig. 1.—Hourly load variation curve.

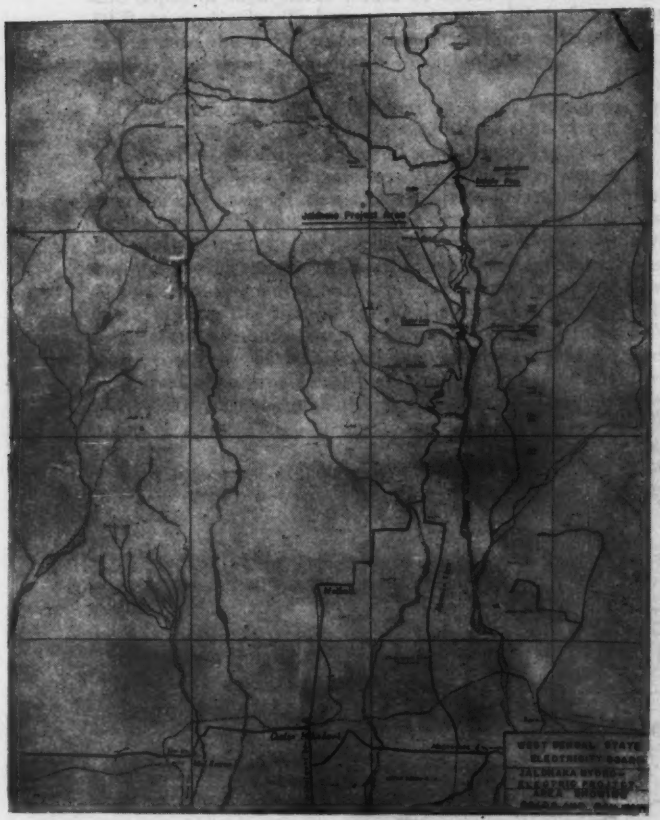


Fig. 3.—Topographical layout of the project site.

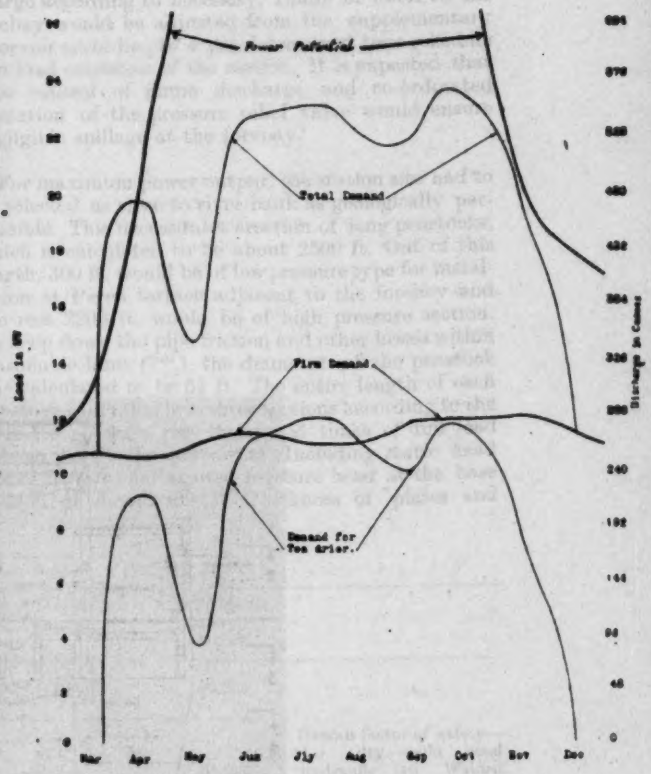


Fig. 2.—Load demand and Power potential.

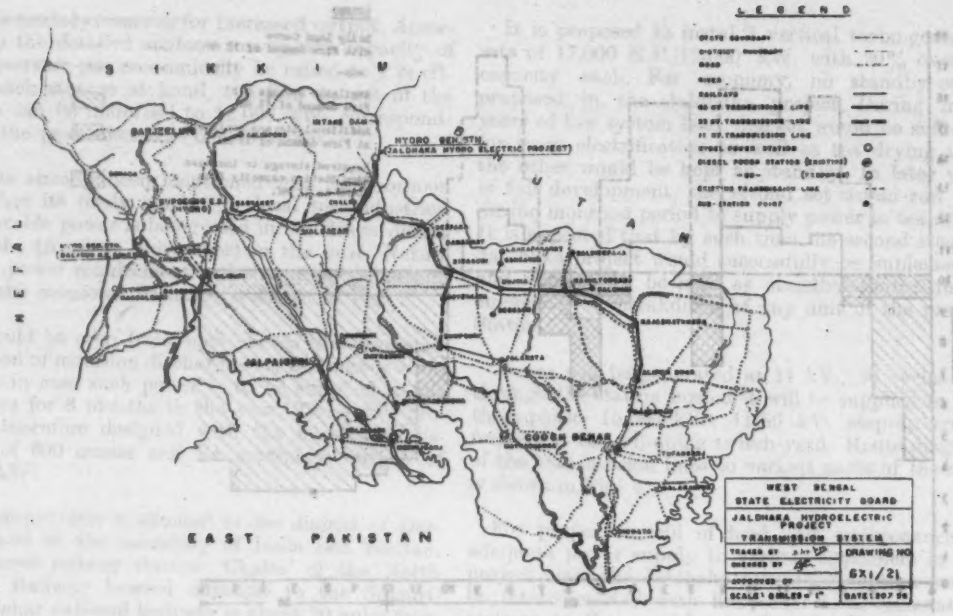


Fig. 4.—Route diagram of the transmission system.

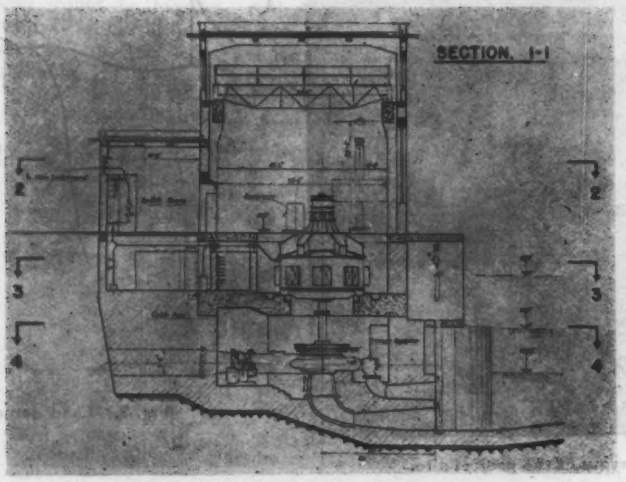


Fig. 5.—Sectional elevation of the powerhouse.

The flume would be designed for a maximum discharge of 700 cusecs including 15% as "free board." When running full, the velocity of flow is estimated to be about 9 ft./sec. with the calculated slope of 1:800. Provision has also been made for loss of head at supplementary reservoir at Gourigong and in intake arrangements at dam site and forebay.

Some parts of the project area are subjected to minor landslides during monsoon period and frequent damages are apprehended during initial years of stabilisation. To minimise disruption of water flow such damages should promptly be repaired and if necessary, the damaged section be easily replaced. For the above reason and also for construction facilities, semi-circular type open flume of steel sheets in convenient unit sizes has been selected in preference to reinforced concerete or closed conduit.

The flume would be 14 ft. in diameter and is to be erected on specially prepared bed with calculated slope along the contour of the hill. The flume would rest on fabricated steel supports and would weigh about 2 tons per ft. run including structural materials. At the landslide areas enroute, it would be protected with reinforced concrete covers. The flume route is encountered with 18 major *jhoras* necessitating special supports of massive construction. Maximum width and depth of such *jhoras* would be about 300 ft. and 60 ft. respectively. To keep away various debris from falling into the flume water, the entire flume surface would be covered with suitable wooden planks.

Geographical layout of the area does not economically justify creation of the forebay bigger than about 0.45 m.cft. i.e. sufficient for full load discharge of the station for about 13 minutes. The forebay would therefore be designed to act as an intake arrangement to the penstocks and to take care of momentary load fluctuation but not as a storage for supplementary supply during peak hours. Further, the nature of the surrounding soil does not permit heavy spillage of water during the time of full load thrown off by the generators without serious scouring effect. The forebay would be of reinforced concrete type and be equipped with trash racks and intake gates to the penstocks with manual and remote control arrangement.

Full discharge of 250 cusecs during summer and 500 cusecs in other times would constantly be drawn through the flume upto "Bhupalikhola," a notable *jhora* enroute, situated at a distance of 12,900 ft. from the intake dam. This *jhora* has continuous discharge varying from 200 cusecs to 1,000 cusecs during the monsoon period and would be utilised firstly as a supplementary source of water during breakdown of service of the above portion of flume and secondly as the first spillway of the excess water down its course to the main river. Final spill would be done at Gourigong supplementary reservoir site located at a distance of 9,400 ft. from the forebay. Quantity of spill at both the places would be controlled by manually operated gate mechanism. With the closing of the gates, the additional water would take about 17 minutes from supplementary reservoir and 30 minutes from Bhupalikhola to reach forebay to replenish the storage for increased load. By timely control of water from Bhupalikhola onwards, the full requirements of the Station can be met on short notice wouthout depleting the storage level at the forebay.

The above arrangement would not however solve the problem of heavy spillage during the time of full load rejection. To keep down the pressure in the penstock within reasonable limit installation of pressure relief valve at the power house end is essential. The relief valve would be of 'water wasting' type with the provision for adjustment of its rated constant discharge according to necessity. Inflow of water to the forebay would be adjusted from the supplementary reservoir according to a pre-determined time schedule and load condition of the station. It is expected that wise control of flume discharge and co-ordinated operation of the pressure relief valve would ensure negligible spillage at the forebay.

For maximum power output, the station site had to be selected as close to river bank as geologically permissible. This necessitates erection of long penstocks, which is calculated to be about 2500 ft. Out of this length, 300 ft. would be of low pressure type for installation at Paren terrace adjacent to the forebay and the rest 2200 ft. would be of high pressure section. To keep down the pipe friction and other losses within reasonable limit (7%), the diameter of the penstock was calculated to be 5½ ft. The entire length of each penstock is divided into three sections according to the ultimate pressure rise therein at times of full load thrown off by the generators. Including static head of 640 ft. total anticipated pressure head at the base would be about 800 ft. Thickness of plates and

Table I

	Length ft.	*Plate thickness inch*	*Weight Tons*	*Min. tensile strength lb/in²*	
Low pressure Section.	300	1/8	11.9	49,250	
High pressure Sec. I.	400	1/2	63.5	58,240	Overall factor of safety—4.5 Qlty.—mild steel hydraulic lap. Welded in standard length of 20-25 ft.
High pressure Sec. II.	600	3/4	143.5	58,240	
High pressure Sec. III	1200	1	382.0	58,240	

other details of the penstocks are shown in table 1. To facilitate transport and erection, two individual pipe lines are proposed, though in view of one unit being used as standby in initial years, it would have been economical to instal one penstock of bigger size with bifurcation at power house end.

The turbines would be of vertical shaft single runner Francis type suitable for coupling with vertical shaft generators. Each turbine would develop with full gate opening 17,000 H.P. at net head of 600 ft. Nominal speed of the unit would be 600 rpm and it would be designed to withstand runaway speed of 1050 rpm for one minute. To avoid cavitation, the runner is to be set almost at the minimum tail water level. The general arrangement of the turbine, generator etc. in the power house is shown in figure 5. In view of lower setting of the turbine runners, the generators are to be designed for installation below the power house main floor. This would firstly reduce the height of the superstructure and secondly permit location of control room on the main floor.

To keep down the pressure rise inside the penstock within reasonable limit of 30%, the governor closing time would be designed to be about 5 seconds. This in turn calls for about 7,00,000 ft. lb^2 as flywheel effect of the generator for limiting the speed rise at full load thrown off within 30% of the nominal speed. To incorporate such high flywheel effect, the generator rotor would be of massive construction and consequently requires larger capacity power house crane.

Each generator would be rated to 15,000 kVA at .80 P.F. with the generation voltage of 11kV. The generator would be totally enclosed self-ventilating type and be equipped with water cooling systems placed inside the stator frame. Each generator would be capable of taking 20% overload for about 2 hours if necessary. Each unit would be provided with all necessary oil and cooling pumps, temperature detectors with alarm contacts etc. Standby D.C. supply would also be provided for emergency. Starting and stopping of the unit would generally be done by manual control but provides for remote operation from the control room. Overall diameter of each generator would be of about 14ft. and weight about 100 tons including the rotor of about 25 tons. During complete shutdown of the Station, emergency supply would be provided from the standby diesel generating units.

As in modern practice, the height of the power house superstructure would be adequate to allow removal of generator rotor and turbine runner from the top and provides ample space for working bay.

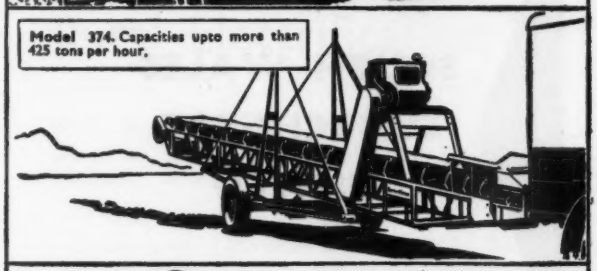
All switchgears would be housed in a gallery in the Station main floor. Main gears and panels would consist of (*i*) 11 kV. bulk power supply to near-by industries, (*ii*) 11/0.4 kV. supply to Station auxiliaries and township, (*iii*) 11 kV. generators and (*iv*) 11 and 66 kV. main transformer units. In addition to above, control panel showing the discharge through each turbine and pressure regulator, water levels of forebay and reservoir would also be provided.

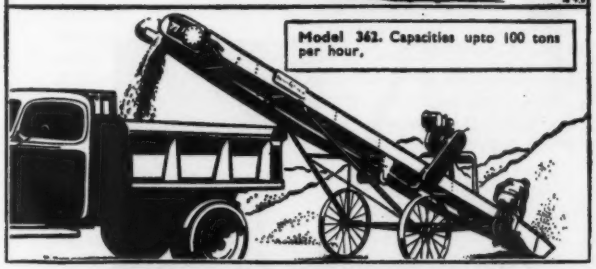
Supply is to be taken from the 11.0 kV. busbar to two 15 mVA 11/66 kV. delta/star connected outdoor, oil immersed, air cooled transformers mounted on concrete rafts. The units are also to be provided with Buchholz protection and the transformer neutral points shall be solidly eartherd with individual isolators. The comparative economics and relative advantages and disadvantages of natural cooled vs. forced water cooled or forced air cooled transformer with reference to the transportation problem, first cost, efficiency, case of maintenance have been studied and ultimately natural air cooled transformers with separate radiators have been selected. Adequate fire protection would be taken in the switch-yard as well as inside the power staton.

Main transmission line would be of 66 kV. and would run on steel fabricated towers. One double circuit 66 kV. line would transmit the entire output of the station to a main sub-station at Chalsa which is located in a central position with good access roads to all parts of the transmission system. From Chalsa, one 66 kV. single circuit line runs east to the Dooars tea areas and terminates at Alipur Duars whereas the other line (33kV.) would be extended upto Kalimpong via Bagrakote. All towns and tea gardens would receive power at 11kV. from the main grid. In all there would be 16 miles double circuit and 65 miles single circuit 66 kV. lines, 60 miles 33 kV. and 90 miles 11 kV. single circuit lines.

Route survey of the main 66 kV. transmission lines has not yet been completed but it is apprehended that most of the route would pass through dense forest in hilly areas necessitating special design to encounter longer span. For maintenance facility the route is to be so fixed as to run close to the existing roads and avoids major landslide areas or places likely to be inundated during monsoon.

This is the first time the State Electricity Board or the State of West Bengal is handling a hydro-electric project of this magnitude in an area subjected to high floods and inadequate rail and road transport facilities from Calcutta. To start full scale construction works at project area involves 10 miles of new road construction, 15 miles of road improvement, building of 2-40′ span bridges, 10 heavy culverts, one township, 25 miles of telephone lines, Post & Telegraph offce, railway sidings with adequate storage therein etc. It is hoped that the Board would be able to complete the project within the scheduled time (1960) and within the estimated provision as approved and sanctioned by the Planning Commission.





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Rural Electrification

By B. N. DATTA, B.E., A.M.I.E.
Divisional Engineer (Planning), West Bengal State Electricity Board

Unlike most of the other States in India, the development of electricity in the public sector in West Bengal started as late as in 1950. But compared to other States the development of electricity in private sector in West Bengal is somewhat spectacular. The total outlay of capital in the private and public sector to-date is about Rs. 42.5 and Rs. 4.5 crores respectively. As a matter of fact, the private sector has already monopolised the remunerative areas viz. Calcutta and suburban industrial areas and the other urban and industrial areas of the State with the State having to electrify non-remunerative areas.

The main bottleneck in the task of rural electrification, as is well known, is the meagre return on investment and as such, it is difficult, rather impossible, to effect the flow of capital from private sector to this field. Nevertheless, it cannot be gainsaid, that rural electrification is the most potent factor to stimulate the economic activities in the rural areas and diversify the national economy which are but the keynote of national planning. It is heartening to note that the Planning Commission has given due acknowledgement to this fact. Private enterprise, whose investment is always motivated by profit, cannot afford to take view of the long-term and all-sided development which rural electrification can accrue to the country. Hence, the public sector which is synonymous with Government, have to take view of that and accordingly embark upon rural electrification schemes. Viewed in this context, rural electrification should be looked upon more as welfare work than as a commercial enterprise.

Problems of Rural Electrification in West Bengal

The position of West Bengal vis-a-vis rural electrification is somewhat different from other States.

Firstly, private sector and Damodar Valley Corporation are satutorily pledged to generate and distribute electricity within certain areas of West Bengal where there is considerable concentration of industries and which holds out further prospect of industrial development. The private sector and D.V.C. having large power stations, and large-scale generation being economic, the tendency in West Bengal is and shall continue to be for State Electricity Board and the other licensees to purchase power in bulk from them for distribution outside their licensed area. This tendency holds for the whole of West Bengal save the northern portion of Bengal which, being far-off and detached from the rest of West Bengal, the State Electricity Board has to generate power themselves. In other States, the development of electricity in the private sector is not so extensive and monopolistic save to some extent in the State of Bombay. Such being the case, other States are going ahead with their programme of electrification, keeping a balance between electrification of rural areas and comparatively remunerative urban and industrial areas. As a matter of fact, rural electrification can be undertaken to a certain extent by balancing the operational deficit of rural schemes by the surplus revenue in other remunerative schemes. This very fact, to a great extent, accounts for the substantial achievement of the Governments of Madras, Mysore and Uttarpradesh and recently that of Bihar in the field of rural electrification.

Two major and distinct characteristics of rural electrification schemes already in operation in West Bengal are low load factor and meagre consumption and that the bulk of the consumption is accounted for by domestic lights and fans. Whereas in other States viz., Bihar and U. P., rural electrification schemes cater mostly to the needs of agriculture and industry viz. tubewell irrigation pumps, sundry small and medium industries. As a matter of fact, U.P. Hydel grid scheme was originally initiated mainly to cater to the needs of tubewell irrigation. At present, of the total maximum demand of about 56,000 KW. in U.P. hydel grid, tubewell irrigation alone accounts for a demand of 24,000 KW. Besides, sundry rural industries in the various states are being sponsored and subsidised by the different State Governments which lend additional justification to rural electrification.

However, towards the end of first Plan period, a few tubewell irrigation schemes have been taken up under Community Development programme and a few more shall be taken up during the second Plan period. Nevertheless, the tubewell irrigation load and other small and medium scale rural industrial load shall continue to be too low compared to those in other states.

The position of West Bengal vis-a-vis rural electri-

fication in relation to other progressive States in India is as follows :

	No. of villages electrified			
	1950	1953	1954	1955
(1) Madras & Andhra ..	1626	1118	2426	2864
(2) Mysore	466	563	649	745
(3) Uttarpradesh ..	416	424	472	544
(4) Travancore-Cochin ..	101	209	345	800
(5) Bombay ..	115	225	261	301
(6) Punjab	53	146	210	310
(7) West Bengal ..	45	65	70	76

Planning for Rural Electrification at National Level

Of late, national planning has received considerable rural bias. It is now recognised that the most important factor to transform Indian economy into a progressively decentralized and co-operative structure is widespread rural electrification. With this awareness, Government of India has established a Rural Electrification Directorate in the Central Water & Power Commission to study and plan rural electrification from all-India point of view. Towards the end of 1954, the Government of India have advanced a loan of Rs. 18.00 crores to the different State Governments for rural electrification. At present Central Water and Power Commission are carrying on a comprehensive load survey of the country. Of the total provision of Rs. 450.00 crores for power in the draft Second Five Year Plan in the public sector, Rs. 75.00 crores is earmarked for rural electrification.

Financial Problems of Rural Electrification

To keep down the cost of the Rural Electrification schemes as far as practicable, U.S.A. and Canada have used single-phase distribution lines with ground return in lightly loaded rural areas. One of the drawbacks of this system is the use of single-phase motor. Single-phase motors of fractional horse-power are not manufactured very largely in India. It may be possible to manufacture bigger size single phase motors in India in near future.

In order to make economy in the rural lines, 11 kV. lines with steel conductors and wood poles have been erected at an average cost of Rs. 6,000 per mile. The maximum capacity of this line is 500 kVA miles which is considered to be sufficient for a rural place.

To lessen the burden of recurring deficit on the State Governments on account of rural electrification schemes, the Government of India have been actively considering some form of subsidy to the State Government in this regard. In July, 1954, a sub-committee comprising some eminent electrical engineers met at Roorkee under the auspices of Central Water and Power Commission. The sub-committee have recommended the following form of subsidy taking into consideration the financial policies generally adopted in our country.

(1) A capital contribution from the Centre to meet upto a maximum of 50 per cent of the cost of rural electrification as outright grant, the balance being made available as loan repayable on usual terms, or

(2) To grant a loan to cover the entire capital cost of rural electrification schemes free of interest for a period upto a maximum of 10 years, repayable in 20 years, thereafter, with interest, from the year following the period fixed.

It is expected that some sort of subsidy would be forthcoming from the Government of India in the near future to accelerate the pace of rural electrification.

Our Achievement to-day and future target

During the course of last five years and a half, we have electrified the villages under the population category as noted below.

	Total No.	*electrified. No.*
(1) Villages with population below 1,000	30,511	nil
(2) Villages with population between 1,000 and 5,000 ..	4,492	70
(3) Villages with population between 5,000 and 10,000 ..	127	19

Bulk of the rural electrification work has been done in the southern portion of West Bengal viz. in the districts of 24-Parganas, Nadia, Murshidabad, Burdwan, Howrah, Hooghly, Bankura and Birbhum. This area has been electrified by drawing different regional network of transmission lines which are fed mainly from three major power systems viz. those of Calcutta Electric Supply Corporation, Damodar Valley Corporation, Mayurakshi Hydro-electric Power House. A few places, because of their far-flung nature and being far-off from the above power systems or the Board's transmission system have been electrified by isolated diesel electric sets some of which shall later on be connected with the gradually expanding regional grid. Future rural electrification in this region is also likely to follow the same trend with gradual augmentation of the said power systems.

The programme of rural electrification in the district of Midnapore has long been withheld as D.V.C's Kharagpur grid sub-station is not yet ready. D.V.C's power shall be available at Kharagpur sometime in 1957 and accordingly a comprehensive rural electrification scheme in the district of Midnapore is now under implementation.

The districts of Maldah and West Dinajpur have also so long been neglected in respect of rural electrification because of the lack of any major power system. Recently, a few isolated diesel power stations have

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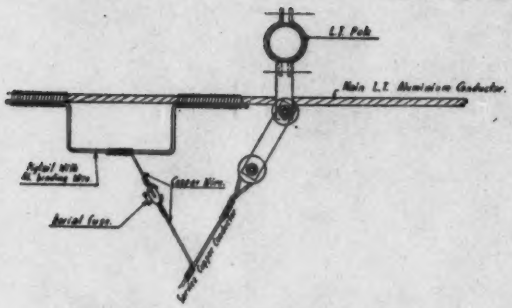
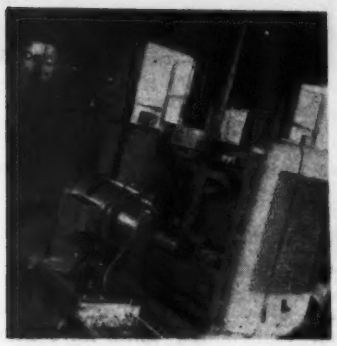


Bi-metallic Joint for Service Connection

been installed and a considerable mileage of transmission lines have been drawn to cater to a limited rural area to start with. The same trend shall continue during the initial years of the second Plan period. A major transmission system comprising of a substantial mileage of 132 kV, 66 kV, 33 kV. and 11 kV. transmission lines which shall be fed from the proposed Durgapur Power Station of West Bengal Government shall ultimately cater to the whole of this area. Generally speaking, these diesel stations serve as pilot power development schemes helping to build up loads in the rural areas in the initial stages ; by the time a sizeable load-development has been achieved the area now being served by pilot diesel sets will be connected to the major power system and the latter shall be further extended to cater to more and more rural areas. When alternative supply arrangement from major power grid materialises, the diesel sets are shifted to other places to serve similar purposes. The diesel plants are well suited for pilot schemes on account of the comparative ease with which they can be transported, installed and commissioned.



Inside of Diesel Power Station at Changrabandha

Powerhouse Building from outside at Changrabandha

The district of Darjeeling, Jalpaiguri and Cooch Behar is very short of power although this region has tremendous potential of hydro-electric power. Here also rural electrification has been done to a limited extent by installing some isolated diesel stations and by drawing some transmission lines from the existing small diesel and hydro stations. This trend will continue in the initial years of the second Five-Year Plan till in the later years two major hydro-electric schemes viz. Jaldhaka and Balasun materialise in North Bengal.

There is yet another region comprising the coastal areas of the districts of Midnapore and 24-Parganas which is not well served by communication facilities and lies outside the economic reach of the major power systems. A few diesel power stations have been installed in this region and a few more shall be installed during the second Plan period. Recently, we have been exploring the feasibility of installing a few wind mill power stations in this region with the help of the Meteorological Department. The usefulness of wind as a source of electric energy depends upon the variable factors of wind itself. The energy available in the wind rises rapidly with increases in velocities and in general, is difficult to utilize economically in velocities below ten miles per hour. The usefulness of wind for generation of electric energy depends upon the number of hours it blows per year at velocity above 10 miles per hour. Another important factor which determines the feasibility of winds for generating power is the distribution of wind throughout the year. For a supply undertaking, it is necessary to maintain the supply round the clock or at least within certain scheduled hours of the day. As continuous supply of useful winds is not possible, a continuous supply of power cannot be guaranteed.

Of late, the land reclamation scheme of Sundarban area has evoked considerable local interest and has assumed tremendous urgency and importance in view of the scope of rehabilitation of displaced persons it offers. This has lent an additional justification for exploring the feasibility of installing wind power unit for dewatering saline water from extensive tract of low lying saline waterlogged area. It is some-what definite that the season of dewatering shall coincide with the season of high wind of the year.

Transmission Lines

Electricity regulations enforced certain restrictions on the design of transmission lines and distribution systems, in the past owing to the fact that transmission and distribution lines were mostly limited in urban and industrial areas, the ground clearances and factor of safety were over-emphasized. These factors are not equally important in respect of rural lines in unfrequented parts. The draft Indian Electri-city Rules which now awaits enactment contains many relaxations of the old rules. The clearances of overhead lines have been reduced for low voltage, high voltage and extra high voltage lines to lower the cost of transmission and distribution. It has been recognised in the draft that the method so long being followed in calculating the factor of safety under the assumption that minimum temperature and maximum wind pressure occur simultaneously in line with British Electricity rules is uneconomic and this coincidence never obtains in our country. The draft provides that the design of overhead lines be based on the loading conditions prevailing in the different regions. We, in West Bengal, have been at present maintaining a factor of safety of 4 for normal condition (i.e., 90°F in still air) and a factor of safety of 2 under the worst loading condition (i.e., 90°F at wind pressure of 20 lbs. per sq. ft.).

Transmission Line Supports

The transmission voltage in use in different rural electrification schemes are 11 kV. and 33 kV. The line supports are : (*i*) Secondhand rails and (*ii*) wood poles.

Railpoles : For the main transmission and distribution systems 90 lbs. rails, 30 ft. long are used as far as practicable. 60 lbs. rails, 27 ft. long are used for spur lines.

Wood poles : Recently we have started using wood

H T line on wood poles along road at Changrabandha

L T Distribution on wood pole at Changrabandha

A railway crossing with overhead 11 kV HT line

poles in our rural transmission lines. Fortunately, North Bengal districts possess rich forests and they are in many places capable of yielding straight poles of sufficient height to meet the requirements of transmission and distribution. In Mysore wood poles have been used for transmission voltage upto 110 kV. Canada, United States of America and many western countries have used wooden poles upto 132 kV.

The main disavantage of wooden poles is their comparatively short life due to inherent defects such as the setting-in of dry rots, etc., and the damage caused by insects and pests. The woods available from the North Bengal forest are felled, open stacked and dried and then treated with ASCU. Notches are cut and holes drilled before the poles are treated, as it prevents the exposure of untreated parts of the wood to weather and destructive insects and pests. The life of the wood poles is comparatively short, being of the order of 15 years. To increase the strength of the line as well as to keep the cost low, in some cases, we have been using wood pole with earth foundation in the tangent locations and rail pole with concrete foundation are used in angle, section or dead-end locations.

Cross-arms

To cut down the cost as far as practicable design of cross arms have been changed from time to time. The figure below shows two types of cross arms which are now being used on rail poles. Advantage is taken of the two holes of the rails for fixing the crossarm bracket which avoids the use of any clamps. The top conductor is fixed on a channel extension piece and this facilitates using shorter rails and thereby reducing the cost of support.

Wood cross-arms are used for rural lines. These are considerably cheaper, avoids bird troubles and increases the insulation level of the system.

Earthing

Individual poles are earthed in case of metal supports of 11 & 33 kV. lines. In case of 33 kV. lines only overhead earth wire for half of a mile on the either side of substation is drawn for protection against lightning.

Conductors

Due to higher price and shortage of copper, aluminium conductors are being extensively used as an alternative. Two types of aluminium conductors have been used.

1. All aluminium.
2. Steel-cored aluminium.

Use of aluminium alloy (Siluabel) conductor is under consideration and a few miles have been purchased for an experimental purpose. These alloy conductors have a conductivity of 53.5% of copper and a strength of 87% of H.D. B.C. wire.

For all low tension distribution lines all-aluminium conductors are now being used. The strength of all-aluminium conductor, although on 35% of theH.D.B.C. wire, has been easily substituted for copper on the same spans, poles, etc. The reason being that normal spans of L.T. lines of 150 ft. and the copper conductors are not pulled to the full tension.

Normal binding is used at the shackle points with a layer of aluminium tape over the conductors and mid-span joints avoided for newly constructed lines. Handling cost during erection of all aluminium conductors are cheaper due to its light weight and only precaution is taken to avoid abrasion during erection.

Substations

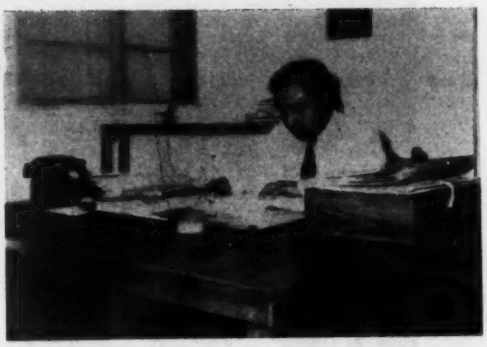
The sizes of the transformers for distribution substations have been standardised at 25, 50 and 100 kVA. Transformers are mounted directly on the H.T. terminal structures.

Lightning arresters are provided in all the rural distribution substations irrespective of the kVA rating of the transformer. Low earth resistance is essential for the efficient functioning of lightning arresters and hence special attention is paid to that.

Correct protection on the low tension side of the rural distribution transformer is extremely essential as the fuse on the H.T. side cannot be relied upon to blow due to any fault in the transformer and overloading because of the difficulty in getting low capacity fuses. Hence rating of fuses should be accurately decided with reference to the rating of the transformer and the load and placed as much close to the secondary terminals of the transformer as possible. Incoming 400 volts terminals of the transformer as well as the feeders are controlled by bridge type recoverable fuses housed in weatherproof kiosks.

[*Continued on page* 32

Transmission and Distribution Network in West Bengal



P. K. GHOSH, B.E., A.M.I.E.,
Divisional Engineer (Technical), West Bengal State Electricity Board

Before 1950 there was no Overhead High Tension Transmission or Distribution Line with a working voltage of 11,000 or more in the State of West Bengal. Thus Bengal, though leading rest of India so far as the installed generating capacity was concerned because of the Calcutta Electricity Supply Corporation, lagged far behind in matter of Transmission and Distribution of electrical power in the State outside Calcutta and coalfield areas.

In the earlier period generation of electricity was confined in a very few moffussil towns and use of electricity was considered doubtful and luxurious as it did not seem competitive to other forms of fuel and motive power. These town undertakings were independent units and each had to install enough plants for maintaining continuity of supply in case there was breakdown of the largest generating unit. This prevented these undertakings from using larger units with higher efficiencies.

As there was no co-ordinated development, some of these generating sets outlived their lives and no new sets installed while demand for power increased. This resulted in restricting connections to new consumers, overloading cables and overhead lines and rendering voltage regulation an impossibility. This happened in most of the areas served by the private licensees.

In order to develop and maintain an efficient, co-ordinated and economical system of electricity an Electricity Supply Act, 1948, was passed and State Electricity Board came into existence in 1955.

But before the formation of the Board a comprehensive transmission and distribution network was planned keeping the growth of demand for power in view by the Electricity Development Directorate of the West Bengal Government.

North Calcutta Grid

In 1950, the first 66 kV. Transmission Line was planned, route survey was done and finally the construction of 66 kV. line was taken in hand from Shyamnagar to Berhampore via Krishnagar under the North Calcutta Electrification Scheme. Bulk power is purchased from Calcutta Electric Supply Corporation from their Mulajore Power Station at a voltage of 33,000 and stepped upto 66,000 by 2-7500 kVA Transformers and then transmitted up to Ranaghat by a Single Circuit Line on towers designed for carrying double circuit to be provided in future. The towers from Krishnagar to Berhampore are capable of carrying single circuit line only.

Transmission Lines

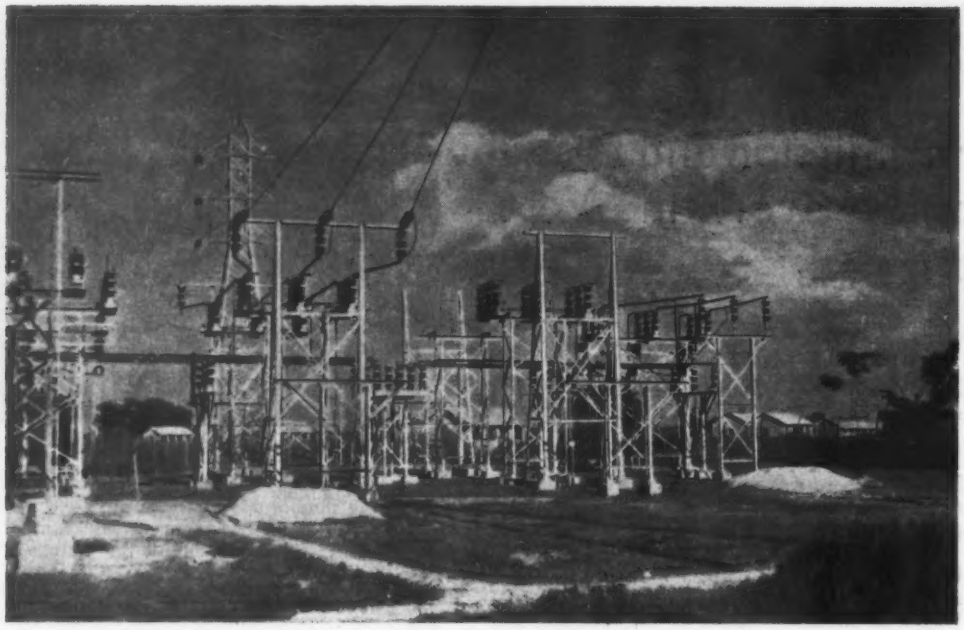
The Transmission Towers are of latticed steel type and carry conductors with an average span of 900 ft. and a galvanised earth wire at the top of the tower providing a protection angle of 42°. Towers used for this Transmission Line are of three types, Type 2°, Type 30° and Type 60° and Type Terminal with maximum deviation of 5°. 0.1 sq. inch stranded copper conductor was used for the Transmission Line between Shamnagar and Krishnagar and 0.1 sq. inch equivalent ACSR Conductor was used for the single circuit line between Krishnagar and Berhampore. The total mileage between Shamnagar and Berhampore is 110 miles and the capacity of the Transmission Line is 15,000 kW. The factor of safety used in the design calculations is as follows :

Conductor	..	2
Earthwire	..	3
Tower	..	2.5

The minimum and maximum temperature taken were 50° F & 130°F respectively. A schematic diagram showing the details of a Transmission Tower is given separately. The vertical spacing of conductors is 8′-6″ vertical while the horizontal spacing is 16 ft. The earthwire is of stranded G.I. wire placed 8′-6″ above the top conductor. The average heights of Double Circuit and Single Circuit Towers are 70 ft. and 62 ft. respectively.

Sub-stations.

Two 7500 kVA Transformers in the Chord Road Sub-station are delta/star connected and the neutral on the 66 kV. side is solidly earthed. The Transformer and the 66 kV. Transmission Line are at present controlled by bulk oil O.C.B. on the 33 kV. side having a rupturing capacity of 750 mVA. The over current protection is provided by tow over-current relays on the 33 kV. breakers and the earth fault protection being achieved by the relay energised by the neutral earthing current transformer on the 66 kV. side. No breaker has been provided on the

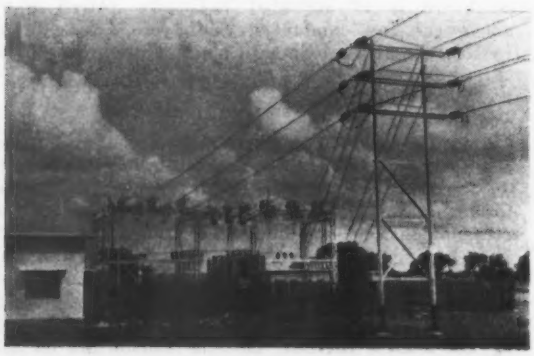


Haringhata Substation

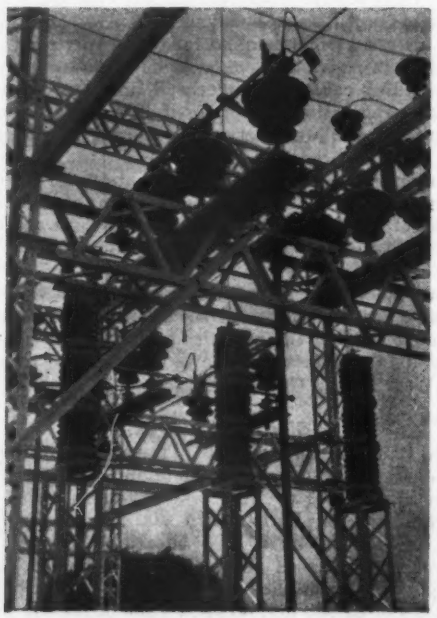
66 kV. side but provision has been kept to instal them within the Second Five-Year Plan period. The 66 kV. Transmission Line has been tapped at various Substations en route and the voltage has been stepped down to 11 kV. by transformers with delta connection on the High Voltage side and star connection on the Low Voltage side. The transformers in these Sub-stations are protected by High Rupturing Capacity fuse on the High Voltage side and the Low Voltage side being controlled by 11 kV, 150 mVA vertical drop-down, truck-type Oil Circuit Breakers. Usually these H.T. Substations being located 2/3 miles away from the township, 11 kV. lines or cables as the case may be and 11.4 kV. Substations have been erected to supply power to these localities.

From the layout of 66 kV. system it will be seen that there is one 66 kV. minimum Oil Circuit Breaker of ASEA make at the Krishnagar Substation to sectionalise the 66 kV Line. This Circuit Breaker is of oil minimum type with auto-reclosing features having two reclosures and two over-current and one earth leakage relay provides the protection of the Transmission Line between Krishnagar and Berhampore. The introduction of this oil minimum type of Breaker cost us only Rs. 42,000/- as against Rs. 80,000/- for bulk oil type Breakers.

Substation at Dubrajpur



Close-up view of a Substation—Dubrajpur



Co-ordination of Insulation of the 66 kV. System.

The first four towers on either side of the 66 kV. Sub-stations are provided with spark-gaps having graded settings. The gap at the terminal tower nearest to the Sub-station is set for an impulse flash over value which is lower than that of the equipments in the Sub-station except the lightning arrestor. The other three towers are given gaps higher than at the terminal tower increasing successively. The spark gap of the Insulators of the terminal tower is set for an impulse flashover value of 312 kV. and the flash-over value of the lightning arresters is 225 kV. and the flashover value of the fourth tower is 420 kV.

South Calcutta Transmission System

The purpose of this Scheme was for draining out and reclaiming a vast waterlogged area measuring about 36 sq. miles by means of electricity driven pumps located on the river Piyali. Bulk power is purchased at 6 kV. from Calcutta Electric Supply Corporation from their Tollygunge Sub-station and stepped upto 33 kV. through two 3,000 kVA 6/33 kV. Transformers and then transmitted to Uttarbhag by a 20 mile-long 33 kV. Single Circuit Line. This line has been drawn on rail poles fitted with Z-type cross-arms.

In this part of the State, the 33 kV. Transmission Line was drawn mainly for supply of power for de-watering purpose from the Pumping Station at Uttarbhag. This line is now being extended upto Diamond Harbour and also to the adjoining rural places. This area is subject to severe lightning and thunder storms. The Transmission line has been designed on the basis of 25 lbs. wind pressure on 3/4 projected area and a continuous earthwire has been used over the Conductors with a protection angle of 30°. So far there have been no cases of breakdown due to storms but there had been several cases of flashing-over due to lightning. Arrangements are being made to put up a surge counter so that the number of lightning stroke per year can be definitely ascertained. This will help in the future design of the Transmission Lines in this area. The atmosphere of this area is salinic and therefore a special type of ACSR Conductors with greased core has been used. No deterioration of the Conductors have so far been observed.

This Overhead Line at present is controlled by Circuit Breakers at the Tollygunge Substation which controls the Circuit from the 6 kV bus to the Transformer. From the layout diagram of this South Calcutta transmission system it will be evident that Govindapur Substation is now working only as switching station with provisions for future 33 kV. circuit breakers. Practically there was no demand for power in this area except that of the Uttarbhag Pumping Station on this grid when the transmission line was first put into commission and as there has been recent growth of load, circuit breakers are being introduced in the Govindapore Substation for sectionalising the transmission line. This design was adopted to reduce the initial capital expenditure and it was considered uneconomic to expend further capital to ensure even better continuity of supply. Duplicate Circuits are the best guarantee for continuity of supply but it should be also borne in mind that in industrial areas the cost of an electrical breakdown is often very much more than the cost of duplicate supply, whereas in urban and rural areas the cost of duplicate supply is very much out of proportion to the risk of failure or the inconvenience caused by such a failure. However, as electricity now plays an essential and important part in our industrial, commercial and social life, planning must be done to provide service as efficiently and as continually as possible while designing and planning the transmission and distribution network in the State.

The Mayurakshi Grid

The Electricity Development and later West Bengal State Electricity Board mainly planned for transmission and distribution of electricity throughout the State by purchasing bulk power where-ever available but later on undertook generation of hydel power in the State, by utilising the 100 ft. dam built at Massanjore in Bihar. From this power station two double circuit 33 kV. transmission lines about 20 miles long have been taken to Suri for supply of power to Suri and then to Pandaveswar Sub-station for electrification of coalfield areas. The 33 kV. double circuit line support consist of rail pole structure properly faced with Z type cross arms and angle iron inverted 'V' arrangement for bearing the galvanised steel earth wire. In the 33 kV. single circuit line, support consists of single rail pole with 'Z' type cross arms. A network of 11 kV. distribution lines has also been drawn for supplying power to different places of the area and the line support used consists of a single rail pole with flat cross arms. The 33 kV. Transmission Line between the Massanjore Power Station and Pandaveswar Substation had to cross river Ajoy the width of which is nearly 3450 ft. A single span crossing would have required towers 303 ft. high above ground costing Rs. 2,50,000/-. It was observed during the survey that if the Transmission Line is diverted upstream advantage can be taken of an island. Soil test was made in this island and it was found that the tower foundations can be safely laid without incurring much cost. The crossing now consists of 3 spans consisting of 1,000 ft. and 1,800 ft. on either side of the island and 1,600 ft. over the island. The cost has come down to Rs. 1,15,000/-.

Single Span crossings are always costlier and, therefore, for all longer span crossing thoughtful investigation should be carried out as to whether spans can be reduced by sinking deep foundations direct on the river beds. For this purpose, advantage may be taken of the experience of the Railway and Road Departments in calculating the soil condition when constructing bridges over the rivers. This matter may be taken up by CWPC so that there may be a record of the river beds, in consultation with Railways and Road Department throughout India which will help future designs of river crossings being made in a very economical way.

North Bengal Transmission System

In the North of Bengal a 16-mile long 33 kV. Transmission line has been drawn between Kurseong Hydro Power Station and Siliguri Diesel Power Station. The Siliguri Diesel Station having an installed capacity of 900 kW. is intended for picking up of load during the peak period as well as supplying power during the dry season when only about 400 kW. of power will be available from the Kurseong Power Station. The Transmission line has been drawn

over the mountains. From the Kurseong Power Station the altitude of which is about 3,000 ft. to Siliguri 600 ft. this transmission line has crossed over the mountain of Himalayas via Kurseong whose altitude is 4800 ft. In designing the transmission line a careful consideration was given to oblique conditions of the area. The maximum span used in this transmission line is 1300 ft. with normal supports of 42 ft. length. The advantage was taken of the mountain peaks and the deep valleys. The sag in these places has been liberally kept with a lower tension in the conductors. Due to the difficulty of transporting 42 ft. long poles the lattice supports were designed in three sections. In this part of North Bengal continuous earthwire has been drawn on our 33 kV. transmission system due to high resistivity of the soil.

Though we have also used continuous earthwire in the 33 kV. transmission system in the part of 24-parganas, South of Calcutta and Mayurakshi area, this method has been dispensed with in the 33 kV systems in operation in other parts of Bengal, in order to further economise the transmission cost. Instead earthwire has been drawn for half of mile on both side of the 33 kV. substation for protecting the sub-station equipments. As lighting is more frequent in the above two areas use of continuous eathwire was considered inportant.

Sub-Transmission Lines

From these 66/11 kV. Substation fairly long 11 kV. Subtransmission lines have been drawn to feed small towns for local electrification. These lines are carried on rail poles fitted with horizontal or V-type cross-arms. Normally V-type steel cross arms are used as an effective safeguard against any bird fault. We have also used wood cross arms in steel support for a few 11 kV. lines and outages are comparatively low. These distribution feeders are usually controlled by 11 kV. circuit breakers with two over-current and one earth leakage relay protection.

Regular interruption reports are being kept all over the state and analysed in order to determine the performance of system and nonsystem faults in the different divisions. The analysis helps to modify future system design, to determine efficiency and responsibility of different divisions and take measures to reduce duration of interruption of power supply. From the analysis we find that most of our overhead faults are caused by birds and in same cases due to lightning and in others due to nature of the vilage arching. In a very few cases insulator failures have been reported. In one peculiar case it was observed that a small pin hole in an insulator caused the breaker to trip when subjected to medium rains and the fault disappeared on heavy rains.

In this connection it may be said the duration of interruption of power supply can be very much reduced if telephone connections are available in our various supply undertakings. Electricity supply undertakings should be given priorities in the matter of telephone connections.

In the Duars area advantage has been taken from the availability of the wood poles from the forest. A ASCU treatment plant has been installed at Cooch Behar and another was proposed at Siliguri. The cross arms used are also of wood and of dimension $4'' \times 4'' \times 4'\text{-}6''$ long. These wood cross arms not only avoid the bird trouble but also attribute to the high insulation level of the transmission line. The treated poles are erected directly in the ground by having the earth well consolidated with a mixture of earth and brick ballast.

To minimise the cost of 11 kV. lines we are using wood poles extensively after suitable treatment of these poles. One such treatment plant has also been erected at our Chord Road Substation.

Specification of treatment unit 2 ft. diameter and 36 inches long.

(1) Pressure cylinder made of steel plates 24" diameter 36' long in 3 sections of 12' each, working pressure 150 sq. inches per sq. ft.

(2) Mixing and storage tank 650 gallons capacity.

(3) Pumps-special contrifugal turbine, filling capacity 1,000 gallons per hour, pressure capacity 198 gallons per hour. This pump is suitable to produce 150 lbs. per sq. inch pressure coupled and driven by 2 B.H.P. 440 Volt A. C. Motor but for quicker filling and raising of pressure for a higher output on timber a 5 H.P. Motor is necessary.

A 26-mile long 11 kV. line has been drawn on such type of treated wood poles between Balurghat and Gangarampur in the West Dinajpur district. In view of the heavy programme of rural electrification which necessarily involves erection of substantial length of 11 kV. lines the study of electrical and mechanical performance is important. Treated wood poles may also be used for extra high voltage overhead lines as is the practice in other European countries as well as in other parts of India. We have not used continuous earth wire over 11 kV. overhead lines on rail poles because of low impulse level of the 11 kV. insulators and thereby achieving appreciable economy in the line costs. Every individual support of our 11 kV. lines has been earthed by a steel or copper wire bolted to the support and attached to an 1" steel rod or G.I. pipe about 8' long driven down to earth. The length of the rod of course varies depending on the nature of the soil. The same procedure has been adopted in case of 33 kV. lines where continuous earthwire has not been used. In some cases of sub-station earthings advantage of nearby wells has been taken to reduce the resistance.

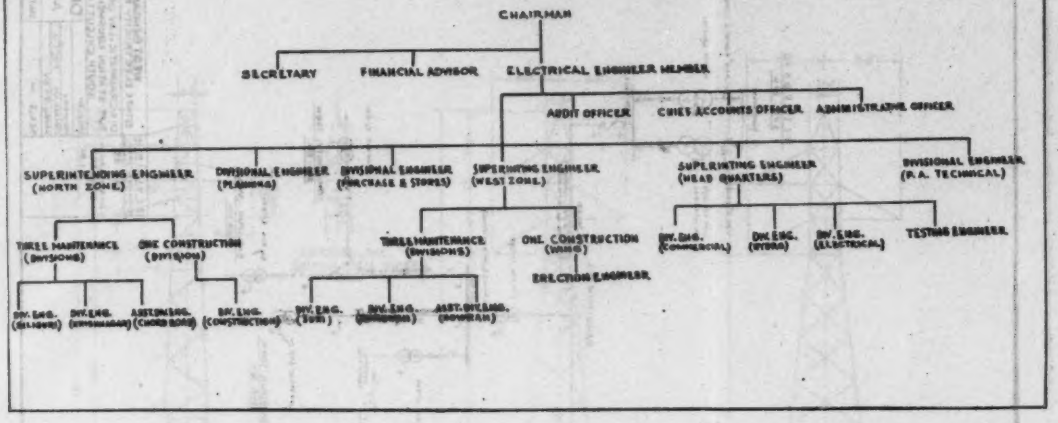
Transformers

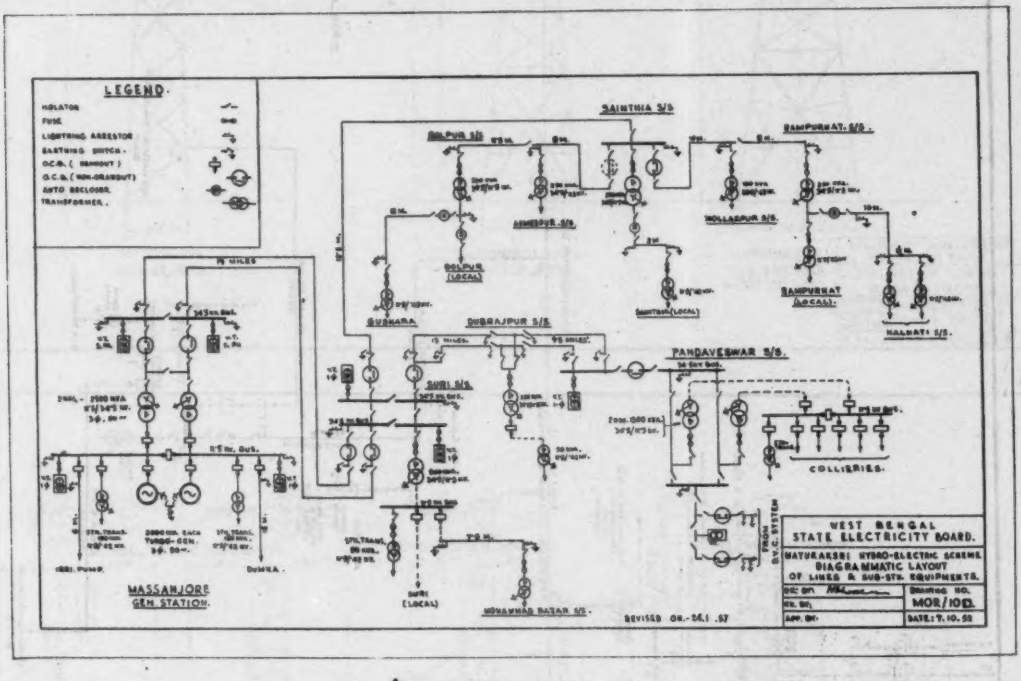
For our 66 kV. substations we have used transformers of capacity varying from 500 kVA to 7500 kVA provided with "on-load" tap changers externally operated to give a variation of plus and minus $7\frac{1}{2}\%$ in the high voltage in ten steps. The impulse level of the 66 kV. transformers is 350 kV.

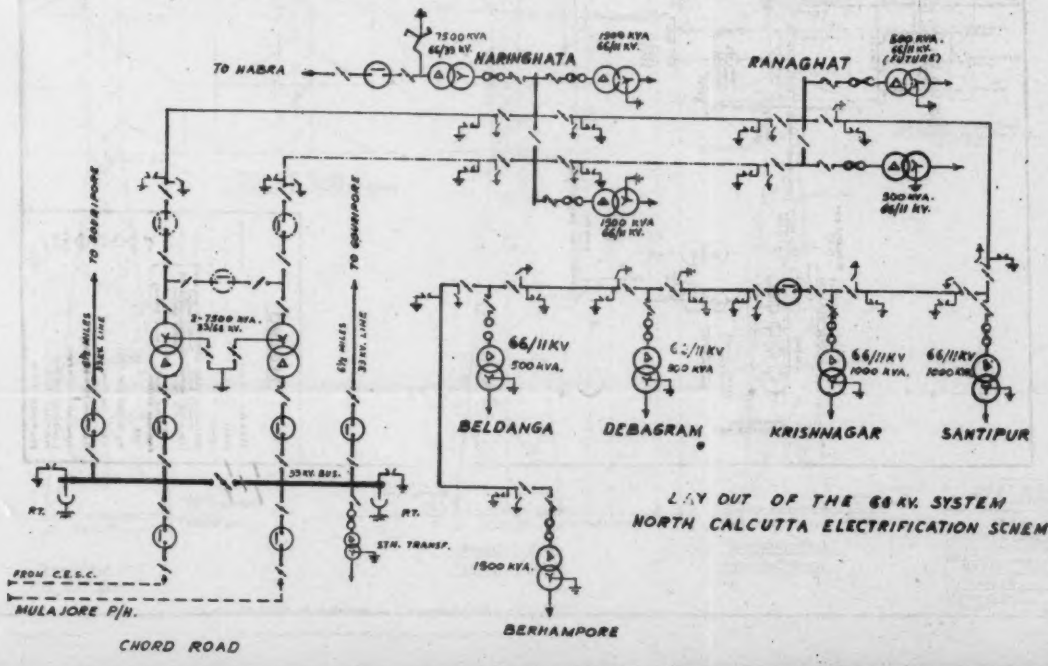
For our 33 kV. transmission system capacities of transformers vary from 250 kVA to 3000 kVA with exception of one or two cases. These transformers are provided with 'off-load' tap changers with $\pm 2\frac{1}{2}\%$ & $\pm 5\%$ variation on the H. V. side.

For distribution purposes, step-down transformers of 11/.4 kV. ratio capacity varies from 25 kVA to 250 kVA. These transformers are provided with

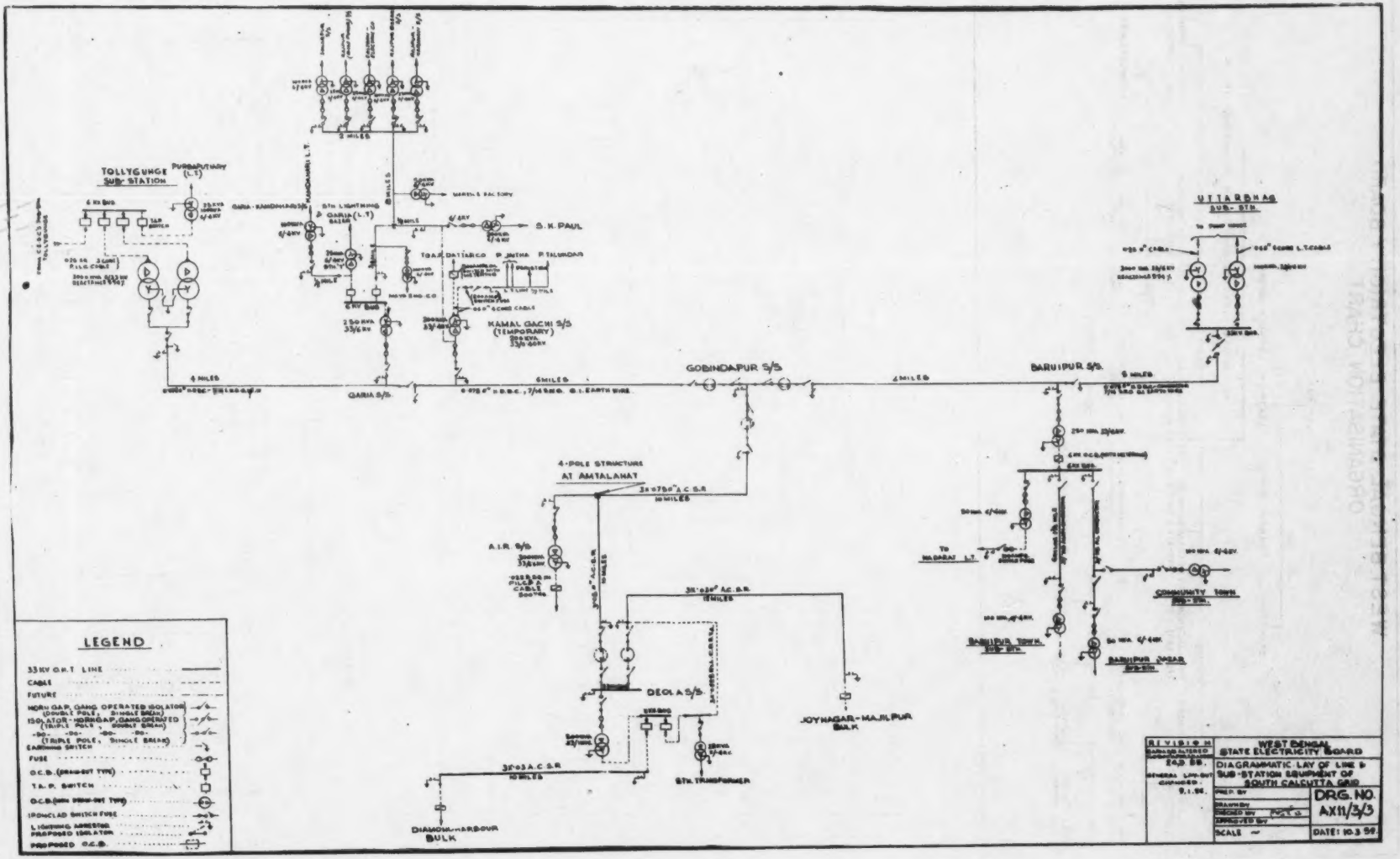
WEST BENGAL STATE ELECTRICITY BOARD
ORGANISATION CHART

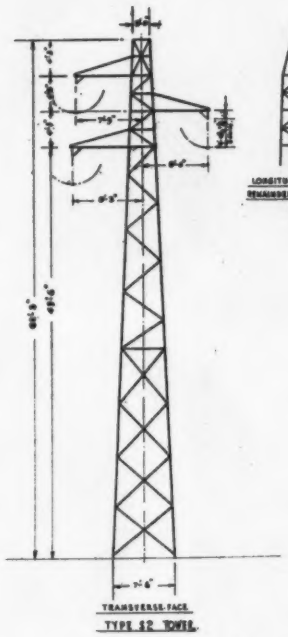






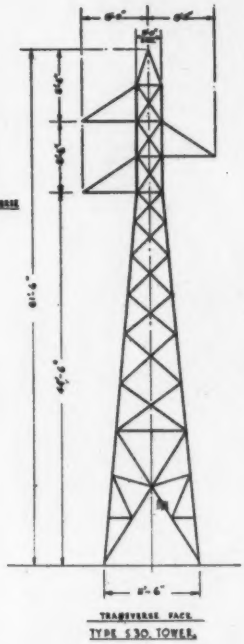
LAY OUT OF THE 66 KV. SYSTEM
NORTH CALCUTTA ELECTRIFICATION SCHEME


TOLLYGUNGE SUB-STATION
PURDAHY (L.T.)
GARIA (L.T.)
S. K. PAUL
KAMAL GACHI S/S (TEMPORARY)
GARIA S/S.
GOBINDAPUR S/S.
BARUIPUR S/S.
UTTARDHAG SUB-STN.
4-POLE STRUCTURE AT AMTALAMAT
A.I.R. S/S
DECLA S/S.
JOYNAGAR-MAJILPUR BULK
DIAMOND-HARBOUR BULK
COMMUNITY TOWN
BARUIPUR TOWN
BARUIPUR JAGAR
4 MILES
6 MILES
LEGEND
33 KV O.H.T. LINE
CABLE
FUTURE
FUSE
O.C.B. (DRAW-OUT TYPE)
T.A.P. SWITCH
O.C.B. (NON DRAW-OUT TYPE)
IRONCLAD SWITCH FUSE
LIGHTNING ARRESTOR
PROPOSED ISOLATOR
PROPOSED O.C.B.
DIVISION
E.H.D. SS.
GENERAL LAY-OUT APPROVED
D.I.No.
WEST BENGAL STATE ELECTRICITY BOARD
DIAGRAMMATIC LAY OF LINE & SUB-STATION EQUIPMENT OF SOUTH CALCUTTA GRID
PREP. BY
DRAWN BY
CHECKED BY
APPROVED BY
SCALE
DRG. NO. AX11/3/3
DATE: 10.3.59

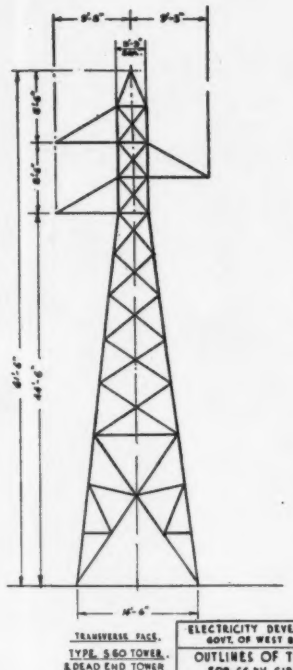


TRANSVERSE FACE
TYPE S2 TOWER.

LONGITUDINAL FACE.
REMAINDER SAME AS TRANSVERSE FACES.

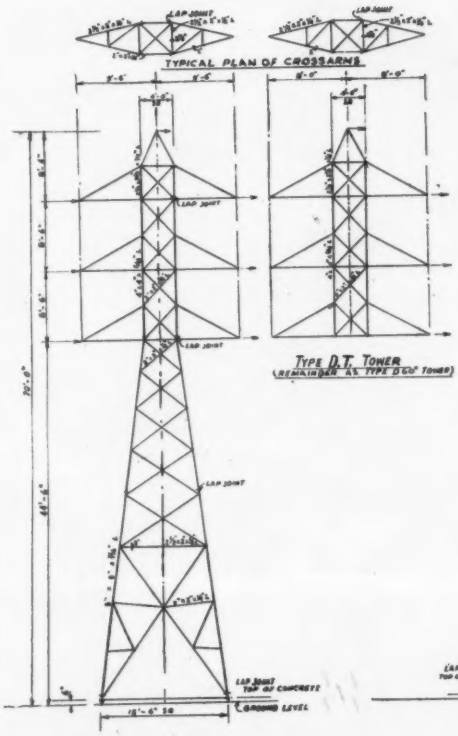


TRANSVERSE FACE.
TYPE S30 TOWER.



TRANSVERSE FACE.
TYPE S60 TOWER.
& DEAD END TOWER

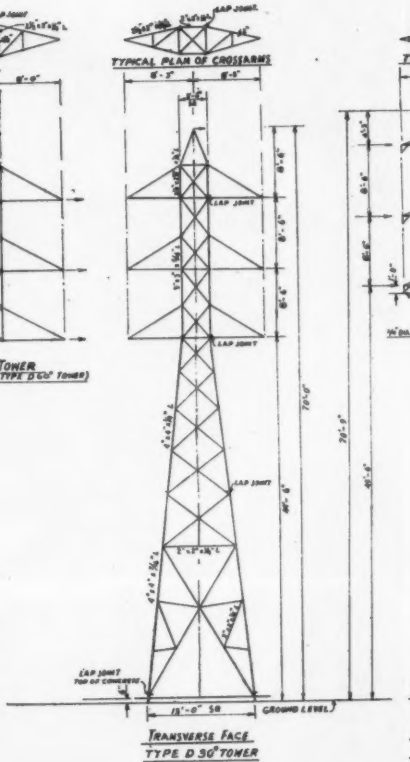
ELECTRICITY DEVELOPMENT GOVT. OF WEST BENGAL	
OUTLINES OF TOWERS FOR 66 KV. CIRCUITS.	
DRAWN BY	DRAWING NO AX1/137
CHECKED BY	
APPROVED BY	
SCALE: 8'-0" 1 INCH	DATE: 14.6.57



TYPICAL PLAN OF CROSSARMS

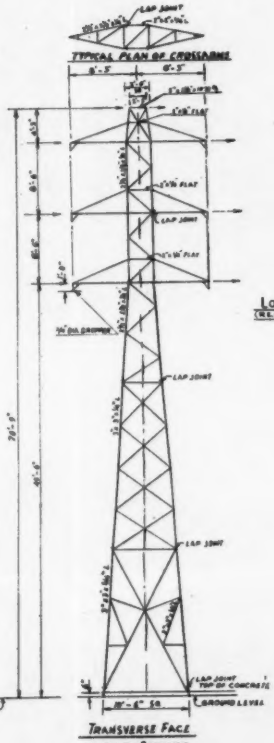
TYPE D.T. TOWER
(REMAINDER AS TYPE D60° TOWER)

TRANSVERSE FACE
TYPE D 60° TOWER



TYPICAL PLAN OF CROSSARMS

TRANSVERSE FACE
TYPE D 30° TOWER



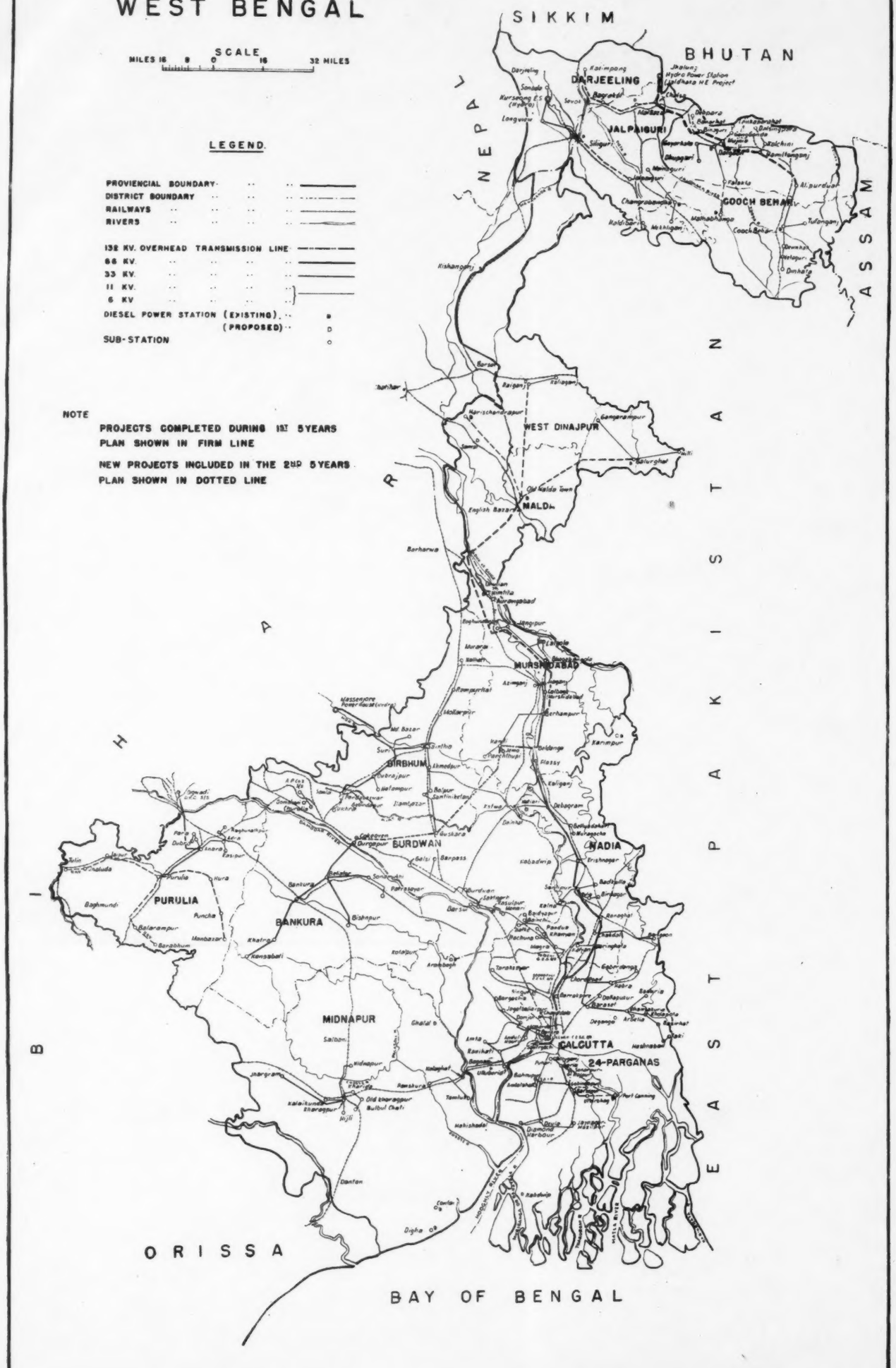
TYPICAL PLAN OF CROSSARMS

TRANSVERSE FACE
TYPE D0° TOWER

LONGITUDINAL FACE.
(REMAINDER AS TRANSVERSE FACES)

WEST BENGAL STATE ELECTRICITY BOARD	
DESIGN FOR DOUBLE CIRCUIT TOWER	
PREP. BY.	DRG. NO.
DRAWN BY.	
CHECKED BY.	
APPROVED BY.	
SCALE:-	DATE:-20.2.57

ELECTRIFICATION SCHEMES IN WEST BENGAL



off-load externally operated tap changing switch on the high voltage side for variation of $\pm 2\frac{1}{2}\%, -5\%$ and -7% on the high voltage side.

All our transformers are natural oil-cooled.

Insulators

For our 66 kV. transmission system we have used disc type string insulators having normally 5 units with dry flash over voltage 250 and wet flash over-voltage 190 kV. & impulse flash over $1\frac{1}{2} \times$ 40 micro secs 420 kV with arcing horns. We have used 6 units for road crossings and two strings in parallel with 6 units in each string for railway crossing.

For our 33 kV. system we have used Pin type insulators having Dryflash over voltage 140 kV, wet flash over voltage 95 kV. and impulse flash over $1\frac{1}{2} \times 40$ micro secs+ve 225 kV and for the strain discs the corresponding voltages are 215 kV, 130 kV. and 355 kV.

The 11 kV. Pin type insulators used have flash over voltage 85 kV. and 54 kV. Wet and impulse flash over 1 $\times 40$ micro secs. and+ve. 140 kV.

We have not yet used glass insulators for our transmission and distribution network but for our Second Five Year Plan projects we have placed orders for 33 kV. & 11 kV. glass pin insulators.

Mileage of Network Completed

We have uptil now constructed 106 miles of 66 kV. line and about 1,000 miles 33 kV. and 11 kV. Overhead Mains and erected 58 H. T. Substations throughout the State. Our Installed transformer capacity is 38,000 kVA.

About 300 miles of low tension distribution lines have been erected in the 103 supply undertakings the Board has now under its control.

Future Schemes

We have electrified some of the small towns and places in the State by erecting Diesel Power Stations and we will have to continue, with the same procedure during the Second Plan though it is considered somewhat uneconomical, as these towns are far away from our existing operating grids. Electrification of towns and rural areas by high voltage transmission system fed from major efficient power sources is the only way by which cheap electricity may be available to the consumers. From our North Calcutta Electrification Grid this result has been some what achieved though there is only one source of supply and the 66 kV. Grid line is transmitting power to places 106 miles away from the generating station and upto another 40 miles by 11 kV. distribution lines. The demand on North Calcutta grid will necessitate a second feeding point and thus it has been provisionally decided to be at Beldanga by drawing a 132 kV. transmission line from the West Bengal Governments Thermal power station at Durgapur. This interconnector will feed Beldanga and the existing North Calcutta 66 kV. transmission line will be extended from Berhampore to Malda via Farakka. It is further expected that the hydro power potential of Teesta river will be utilised for generation of electricity in the northernmost part of the State. But as the growth of load is in the southern districts of the State it will be probably economical to have Extra High Voltage transmission lines drawn to connect between North and South of Bengal. This is the practice in European countries. Where long distance transmission lines have interconnected power stations and by which it has been possible to generate power at the most economical station according to the varying demand throughout 24 hours of the day and 365 days in the year.

The Board proposes to erect 700 miles of new transmission and distribution network throughout the State during the Second Plan period.

Technical Personnel

All these work will require trained technical personnel to solve the different problems of high voltage transmission and distribution network. In the year 1950 the department had only twelve qualified engineers and there are now about 130 such engineers looking after construction, maintenance and operation work.

The problems confronting the engineers for operation and maintenance of the numerous component of power plant and equipments comprising a transmission and distribution network are many and it is the engineer's duty to try to maintain the voltage at all points on the system at correct level, to arrange so that the various component parts are not overloaded, to maintain efficiently all plants associated with the system, to repair faults within the minimum possible time limit and last but not the least to see that all safety measures are adopted and 'permit to work' card system is introduced in which the apparatus on which it is safe to work is clearly defined.

Training of Personnel

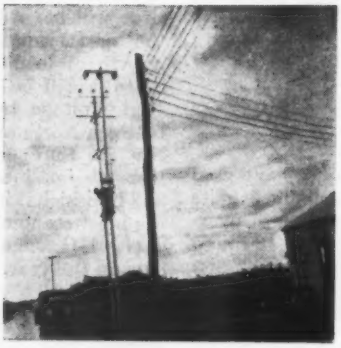
Training is of utmost importance to the electric-supply industry as a whole. We are taking 14 graduate engineers every year for imparting training in construction, maintenance and operation of transmission and distribution systems and absorbing them as engineering assistant on completion of their training.

We are also recruiting diploma holders in engineering and ordinary science graduates to be trained for maintaining supply undertakings and construction of new lines and substations.

In this connection it may be mentioned that the American Productivity team which visited England opined that standard of technical training for districts staff was too high and that men with university degrees could be better employed on more specialized technical work. We are in dearth of qualified technical engineers and we must see that those we employ are properly utilised so that in furture their services may be available for higher technical and administrative work.

Continued from page 26

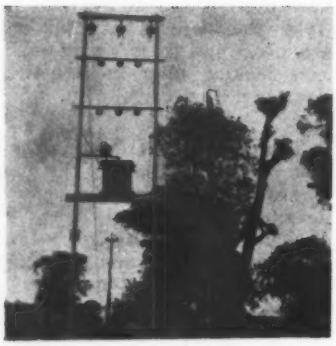
Combined HT-LT line on wood pole Mekliganj



Left : **Step up Substation**
Right : **L T Distribution on wood pole Changrabandha**

A Corner Pole of H T Line with road crossing Guards. The general configuration is Horizontal but the angle and section poles are Vertical at Changrabandha

The trunk H.T. lines 33 KV. as we as 11 kV. catering to a number of rural places are protected at the main substation end by circuit breakers. A number of spur lines issuing out from the trunk lines are controlled by 11 kV. pole-mounting type oil circuit breakers with autoreclosing features. The auto-reclosing circuit breakers provide two instantaneous trips and two delayed trips. 11 kV. overhead transmission lines, as is experienced everywhere, are very prone to outage due to lightning and bird fault. About 80% of the faults are transient in nature. The auto-reclosing circuit breakers clear the transient faults through two instantaneous trips. The delayed trips would not occur unless the fault is of persistent nature and consequently outage of the line due to transient fault is avoided through one or two system jolts.



Left: **Step down substation at Mekliganj**
Right: **L T Distribution on wood pole**

This auto-reclosing type circuit breakers hold out immense prospect of application in our future rural electrification schemes and more so in tubewell irrigation schemes. The 11 kV. trunk line controlled by such autoreclosing circuit breakers with individual spur lines controlled by fuses with characteristics of the latter so chosen as to let it remain inoperative during the two instantaneous trips and allowed to blow during the delayed trip period of the former would localise the fault and minimse the extent of interruption of supply. A cluster of tubewell pumps being served by a main trunk line with a number of spur lines issuing therefrom would lend itself ideally to a switching scheme comprising an autoreclosing type breaker with co-ordinated fuses on spur lines. It is contended that co-ordination of characteristics between those of autoreclosing circuit breakers and fuses is somewhat difficult, at least more difficult than as among a number of fuses. So it is argued that the better practice would be to install fuse immediately after and in series with autorecloser and co-ordinate the characteristic of the said fuse with the fuses of the spur lines. The autorecloser would under such scheme just provide one or two instantaneous trips under transient fault thereafter close with fuses on the trunk and spur lines having to take discriminative care of the persistent faults in respective spur line.

Initially we do not venture to take to wide-scale experimentation with such auto-reclosers. Our experience with a few auto-reclosers installed recently in our rural lines would be our guide in this respect.

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Electricity in the Countryside

By M. DATTA, Ph.D. (Edin.), M.Sc. (Tech.) (Manch.), M.Sc., M.I.E.E. (Lond.)
Superintending Engineer (Headquarters), West Bengal State Electricity Board

Emphasis has been laid both by the Central and the State Governments on the industrial development of our country during the Second Five Year Plan period. To achieve rural economy, development of cottage and medium sized industries over large scattered areas is called for. Power is an essential prerequisite for initiating such a scheme. The paper discusses means for the provision of electricity service at the lowest cost to the largest number of consumers, in order to promote small scale cottage industries, pump irrigation, etc.

Rural Load in our country

In our rural areas the first and obvious use of electricity would be for lighting with some pumping to provide a supply of clean water. Despite the benefits of electricity, nobody in the countryside at present income levels could use it for any other labour saving purposes.

The major agricultural communities do not even enjoy the primary urban amenities which are so often beyond their means. Unless it is possible to encourage the development of rural industries by a properly planned policy and thereby create opportunities for employment in the villages, there will be great difficulties in developing rural electrification.

It is, therefore, advisable that rice hullers, flour mills, oil crushers, cotton ginning, sugar cane crushers, creameries, saw mills, jointers' shops and such processes intimately connected with farm production should be developed in rural areas not only to supply local needs but also for exporting to urban areas.

Steps to accelerate development

To accelerate the development special attention could be given to :

(*a*) Assisted Wiring Schemes—The householders with limited means may have their premises wired on deferred payment terms and obtain electrical appliances on hire-purchase.

(*b*) Tariff—An attractive combined rate system of charge should be introduced and a single meter installed to measure all consumption in the house.

(*c*) Service Charges—A reasonable length of service line should be given free and facilities given by making service charges payable in instalments for greater lengths.

(*d*) Maintenance and Service to Consumers—A servicing organisation should be set up whereby, for a reasonable charge, any fittings and installations can be promptly repaired.

Extension of Supplies to rural areas

In rural areas the ratio on the additional capital expenditure per consumer to the revenue derived from the supply is unduly high. Considered upon their own merits, many rural extensions may be uneconomic. As, however, the Government considers electricity supply to be partly a social service, the approach must necessarily be different and account must be taken of the indirect benefits to agriculture and to the general welbeing of the rural population.

From the above, it will be appreciated that most rural schemes must be treated differently from the urban ones. The rural population is less able to guarantee the costs of rural electrification. However,it is not fair to expect urban consumers to subsidise the extensions and, therefore, either subvention must be obtained from Government for this service or the extension must be carried out on the estimates of long term returns and the accounting for this service kept separate.

Recommendations

With the above in mind, the following principles are recommended for rural extensions and service connections :

1. That the State Organisation on receipt of an application for service from a potential consumer shall make a survey to determine what other possible consumers may be economically served along with the applicant and estimate the capital cost of the extension.

2. That working in line with the British Act, the Organisation may be allowed to obtain from the prospective consumer a guarantee of an annual revenue not less than 20 per cent of the new capital expenditure on the extension of mains and services, for a consecutive period of 5 years, the guarantee thereafter lapsing.

3. That should the estimated revenue extending over a period of 5 years be equal to the cost of extension of mains and provision of service connections, the scheme would be proceeded with, the Organisation bearing the full cost.

4. Should the estimated revenue extending over a period of 5 years be less than the estimated capital cost of extension, the deficit will be obtained from the applicant.

5. That in the case of an application from a village or community, the estimated cost of supply should be weighed against the estimated revenue over ten years.

6. That should the annual revenue not be equal to 10 percent of the estimated cost, the Organisation will place the case before Government with a request for an outright subsidy to meet the 10 year deficiency.

7. That the first 100 feet of service will be laid free, irrespective of location and for all service above this limit, the consumer shall pay the actual cost.

8. That the cost of future strengthening of service lines to meet increased demand may not be leviable from the consumer if the load condition justifies.

Some protection is necessary against the Organisation incurring heavy expenditure due to some of the consumers having agreed to take energy for a number of years and then abandoning the adventure or the premises. This risk is rather serious in the case of of power supplies where works are started and then wound up. It also arises in the case of isolated country sites where electricity may be installed with little or no use.

The consumer will be required to guarantee a minimum annual payment to cover generally charges on new capital expenditure that will be borne by the Organisation and the cost of energy.

Nature of load, stability of consumer and possibilities of load developing would be considerations in fixing the figure for minimum guarantee.

All the above recommendations are not enforceable except by legislation or by a Special Order, as they are unauthorised departures from the Statutory Provisions in the Act.

Technical Considerations

For decreasing the first cost, the following line of approach is suggested :

(*a*) *Standard System*

From an analysis of the cost of transmission at 33 and 11 kV it appears that the use of 11 kV. .1 sq. inch. cu. eq. construction will be very economical upto 17 mW miles assuming conditions of .9 power factor and a voltage drop of 10%. Generally the kW/mile figures in this country will be lower and hence .025 sq. inch and .05 sq. inch 11 kV construction may be carried out with advantage. The kW/mile figures applicable to these conductors are 6 mW miles and 10 mW miles respectively for a voltage drop of 10% at .9 p.f.

Over 17 mW miles the balance is in favour of transmission at 33 kV for distances not exceeding 30 miles between main substations.

Suitable clearances for 33 kV operation may be initially provided at a little extra cost in an 11 kV line structure so that such a line can be easily converted to a 33 kV line by changing insulators in case the load requirement necessitates such conversions.

(*b*) *Single phase versus Three phase*

The main backbone of high voltage distribution should be three phase at 11 kV A.C. but the majority of spur lines, unless for heavy loads, should be single phase. For all distances over 500 yds. and 11 kV, single phase line is the sheapest. Single phase supplies may be given to agricultural communities, each village or locality having its own transformer in small units not exceeding 5 to 20 kV to feed a 2 wire 230 volts or 3 wire, 230/460 volts distribution network.

In the Irsh Republic the sizes used are single phase 10 kV/220 V 3, 5 and 15 kVA ; single phase primary 10 kV/ secondary with 2 windings of 220 volts with the provision of series/parallel connection (capacity upto 33 kVA).

The fractional H.P. single phase motor which is most commonly used in rural electrification differs little in price from a three phase motor. Although the larger single phase motor of 1-3 H.P. is dearer than a three phase motor this disadvantage disappears when we consider the extra cost of three phase line and transformer. Furthermore the revenue from a unit of electricity is usually the same whether the supply is single phase or 3 phase although the latter is more costly to distribute. There is also the simplification in the farm wiring and metering if single phase system is adopted. The same meter will then do for domestic and motive power on the farm.

For 11 kV distribution the use of unearthed lines to B.S. 1320 on wooden poles is recommended as it is less affected by lightning than an earthed line. In this type of construction there will also be no necessity for using devices to prevent bird-faults. On unearthed lines, the steel structure comprising of :

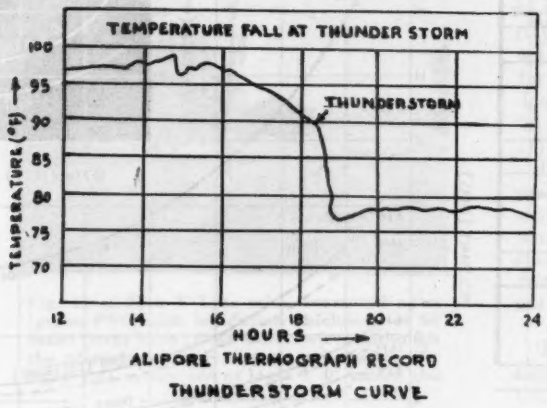
(*i*) Transformers pole and poles carrying isolators
(*ii*) Terminal line pole (with cable) must, however, be earthed in the normal way.

P. O. Cradles at road crossings and railway crossings have been surperseded by crossings having insulated aerial wires in the crossing span. The aerial wires are insulated with green P.V.C. 60 mil radial thickness (made to a P.O. specification.) (Fig. 1.)

(*c*) *Line Conductors*

For all high tension lines, where the conductor size is more than .05 sq. inch copper equivalent, A.C.S.R. conductor is recommended. For economic reasons aluminium alloy lines of lower sizes viz: .03 sq. inch may be used particularly where the span lengths seldom exceeds 350 ft. When using any aluminium conductor one should watch the line stringing tension under normal everyday conditions. No aluminium conductor should be allowed to run at a normal condition exceeding 20% of its ultimate tension without vibration dampers. The Irish Board have found that

FIGURE - 2



ALIPORE THERMOGRAPH RECORD
THUNDERSTORM CURVE

FIGURE - 3

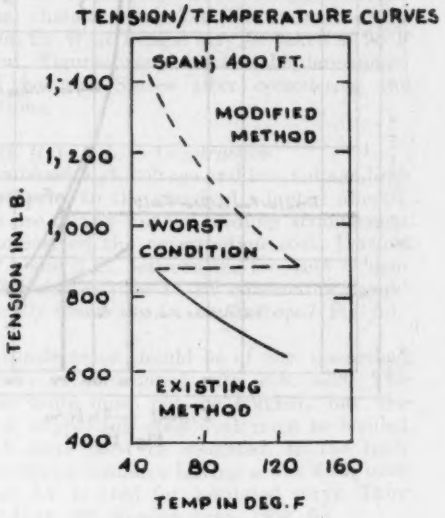


FIGURE - 4

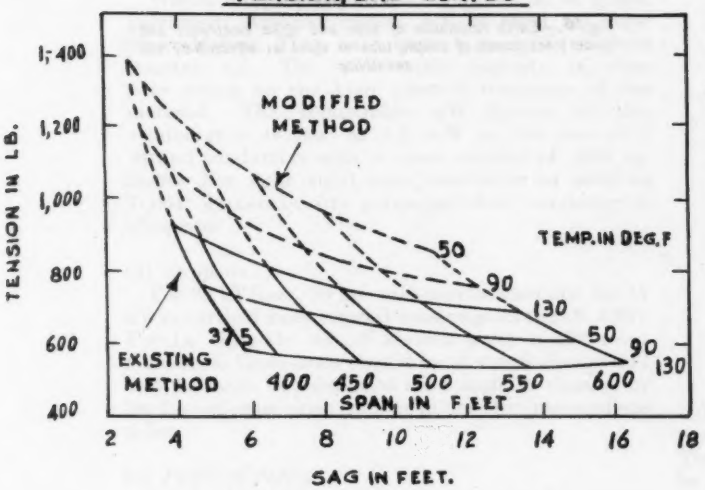
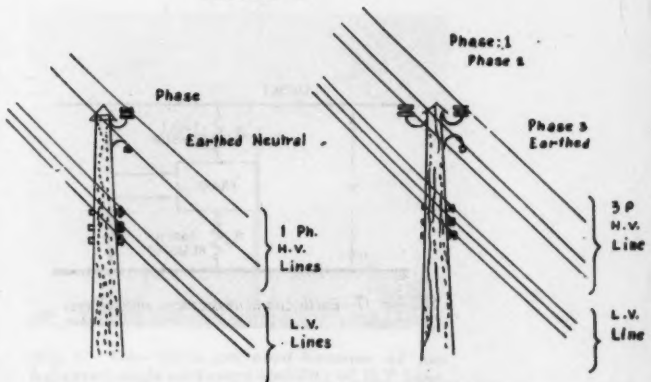
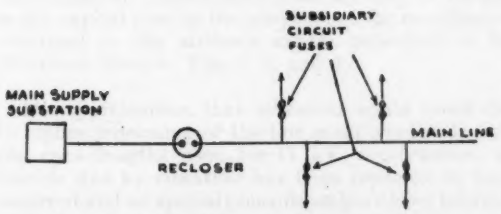


FIGURE - 5



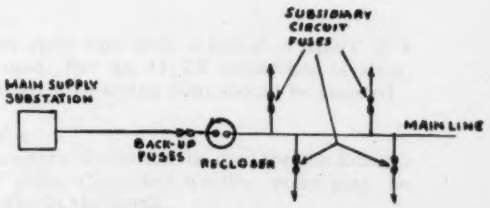
COMBINED H.V. /L.V. OVERHEAD LINE CONSTRUCTION

FIGURE - 10



Recloser of the lock-open type installed in the main supply network with subsidiary lines fuse-protected.

FIGURE - 11



Recloser of the hold closed type installed in the main supply network with back-up fuse protection. Subsidiary circuits fuse-protected.

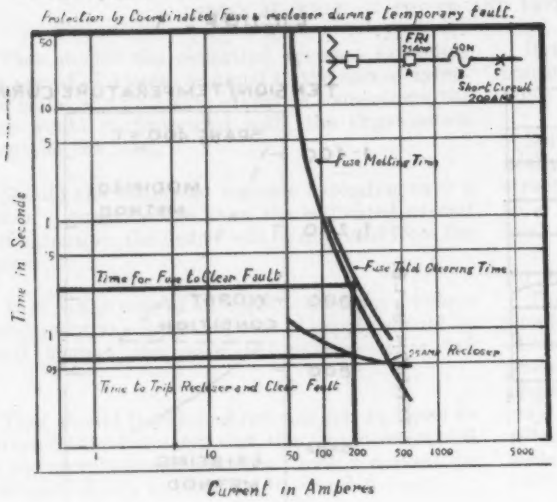


Fig. 12

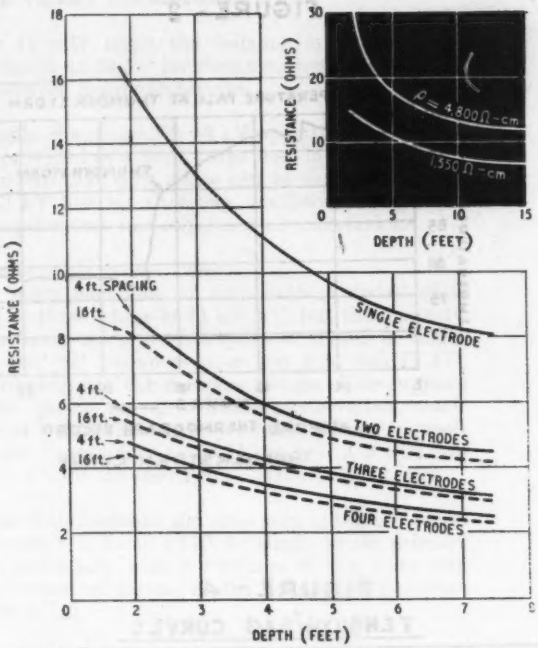


Fig. 16.—Earth resistance of tube and spike electrodes and (inset) resistance of simple tube or spike as affected by soil resistivity

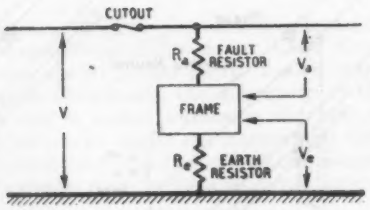


Fig. 17—Earth circuit resistances and voltages

Fig. 1.—A 11 k V Line with insulated span (green PVC with insulation thickness of 60 miles) over bare Post office wire. Although the photograph may appear otherwise, the light P.O. wires are at least 3′ 0″ under the power line.

use of A.C.S.R. is cheaper than aluminium alloy even for smaller sizes of lines. They use "Robin" (.04 sq. inch. cu. equiv), "Swan" (.02 sq. inch eqiv.) for 11 kV and l.v. lines and "Turkey" (.013 sq. inch cu. equiv) for l.v. services.

Where the prospective load is known to be small, galvanised steel conductors can be used for rural electrification. They have quite a good life in clean country air. The mW miles capacity is very poor owing to the high internal reactance of the material. The comparable mW figures for this conductor is as low as 1.3 mW in the case of 7 strand conductors with a cross section of .058 sq. inches For light rural lines conductor as small as 7/.064″ 45 ton quality galvanised steel conductor is adequate.

(*d*) *Supports*

For 33 kV lines, 90 lbs. rails may be used and for 11 kV unearthed lines treated wooden poles to B.S. 1990. For l.t. lines the use of wooden poles is also recommended. Cross-arms should be of simple design and may be made of galvanised steel angle or channel or hard wood cross arms (similar to oak) for intermediate poles.

(*e*) *Factor of Safety*

The load conditions in our country are less severe than in Britain ; and there is also less difference between loaded and unloaded conditions. The present method of calculating the factor of safety of lines assuming worst wind load to occur at minimum temperature when the conductor stress is high, is very uneconomical. Considerable economy may be effected in the capital cost by the adoption of the modification discussed in the author's article published in the Electrical Review. Fgs. 2, 3, and 4.

The apprehension that vibration would result due to higher tensioning of the line is unfounded as with the span lengths used for 11 kV construction, no trouble due to vibration has been reported to have occurred and no special precautions have been taken to protect against vibration.

It is recommended that the factor of safety should not be less than 4 for normal every day conditions and that the tension during the worst load condition should not be more than 60% of the ultimate strength. The worst load conditions for each zone should be prescribed by an official regulation having reference to the actual climatic condition. The normal every day condition for West Bengal may be taken as 90°F without wind. Figures would have to be determined for each of the other States after considering the local conditions.

(*f*) *Combined H.V. / L.V. Construction*

Use of combined high voltage and low voltage lines on the same pole, to the standard adopted abroad, without the use of any further cradling arrangement would economise on the construction cost. Vertical clearance of about 3 ft. between the two sets of conductors is desirable and the 11 kV conductors should not be vertically above the l.v. conductors. (Fig. 5.)

The h.v. construction should be of the unearthed type, generally in accordance with B.S. 1320. The l.v. insulator bolts must not be bonded, but the h.v. insulator supporting steel work must be bonded together. All stays must be insulated. In the Irish Republic procelaim insulator having a wet flash over voltage of 20 kV is used for insulated stays. They are cheaper than the wooden type. (Fig. 6.)

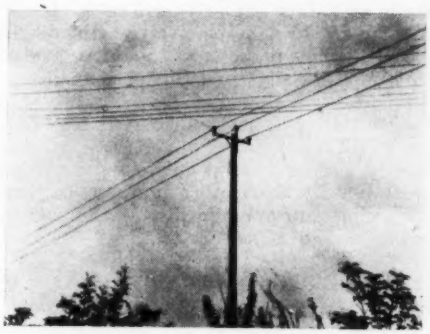


Fig. 6.—Two stays are used because of unbalanced angle and extra stability of H T Line. Note the stays are insulated with porcelain insulator

The span lengths must be in accordance with l.v. practice. It is not essential to run a separate earth. The normal phase and neutral l.v. conductors can be supported in the usual formation used for l.v lines.

(*g*) *Anchor Rodand Plates*

Prefabricated concrete plates for heavy angle construction and screw type anchors for light construction may be adopted.

(*h*) *Stay-wire*

Galvanised steel wire with a factor of safety of 4 should be used. For an 11 kV unearthed system, insulators fitted with arcing horn should be inserted.

(*i*) *Foundation*

Square concrete blocks can be used for the foundation of rail poles. Creosoted wooden poles may be placed directly in the earth.

(*j*) *Size of Transformers*

In selecting a transformer size for an individual load, it is important to make sure that it will not be too large for a long time to come not only on account of the first cost but also on account of the core losses. It is recommended that the smallest standard size

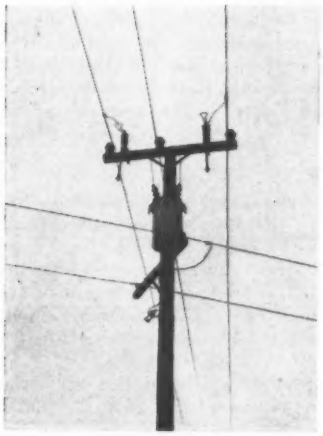


Fig. 7.—5 kVA transformer on 3 phase 10 kV line with H T and L T fuse shown. The top cross arm is 6′×3¼″×4″ oak. The transformer is earthed and fuses shown open.

Fig. 8.—5 kVA transformer or Single phase 10 kV end pole with L T running in three directions. No H T fusing except on tapping from 3 phase lines.

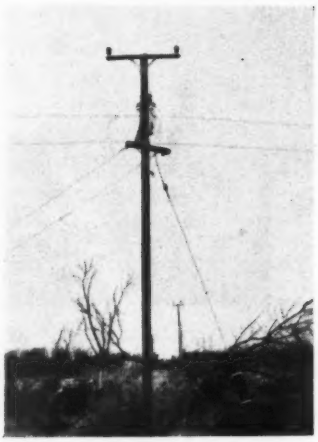


Fig. 9.—A 15 kVA Single phase transformer on end pole with single bolt fixing.

of single and three phase transformer should be 15 kVA and 25 kVA respectively with qualification that 5 kVA single phase units should be available for small groups of consumers. (Fig. 7 & 8).

The Midlands Electricity Board provide small transformers with taps on the low voltage windings—these connections being brought out to separate insulators on the tank. By this method it is easy to change the taps on the transformers whilst up the pole, without removing the lid.

The Irish Board use 3 and 5 kVA transformers capable of 100% overload for upto 4 hours. These are adequate for small groups 3-5 consumers. Transformers are sealed round tank to NEMA spee and l.v. tappings 5% are brought out as practised in the Midland Electricity Board.

Inter-changeability of transformers is generally easy on pole mounting, even where different manufacturers are involved as the normal standard upto 15 kVA single phase transformers are supplied with single bolt fixing only. (Fig. 9.)

(*k*) *Joint Line Construction*

Where both l.v. power lines and communication circuits are maintained on the same side of the road, the advantage of joint line construction with the power conductors (which are stronger) placed at a higher level, may be taken. This is a reciprocal arrangement, some times the communication circuit carries the low voltage power lines or vice versa.

(*l*) *Earth return*

The experimental use of single line construction for rural distribution on wooden pole with galvanised steel conductor using the ground as a return path is suggested.

(*m*) *Insulated Neutral H. V. System*

In mountaneous terrain, the ovehead lines are subject to adverse climatic conditions and are often subject to transient faults. These are non-persistent faults caused by lightning or by twigs blowing in a high wind to an overhead line and causing the circuit to trip out. The advantage of using h.v. overhead lines (upto 11 kV) with unearthed neutral may be considered from the point of view of maintaining continuity of supply. This is permissible provided that the total earth capacity current does not exceed about 3 amperes as below this figure arcs to earth are not self-sustaining.

It would mean however that in the event of a phase fault to earth the overvoltage resulting at some point of low insulation would lead to a double phase fault and supply would be interrupted. This may be eliminated by providing for some indication to be given on the occurance of an earth fault on one phase. The use of neon type indicators tapped off the bushings of the 11 kV switchgear will give a bright glow under normal condition but in case of a sustained earth fault the appropriate lamp will cease to glow.

The alternative is to use earthed construction and to provide some means of high speed auto-reclosing so that all transient faults are restored without the loss of supply by the operation of an automatic recloser or reclosing circuit breaker. It is then possible to protect the rural lines by fuses as all transient faults are thrown back on the recloser.

(*n*) *Protective Gear*

The choice of protection for rural distribution systems is limited by economic considerations. Since rural lines are usually long, the amount of automatic protection should be as small as possible and should be installed in place which can be easily approachable.

Statistics indicate that most of the line faults are of a transient nature i.e., the fault is cleared as soon as the line is de-energised and hence the supply can be restored immediately. A co-ordinated fuse system will definitely minimise the outages caused by persistent faults but could not prevent outages due to temporary faults.

It is common practice to provide fuses on every pole transformer but experience is that during a lightning storm many such fuses blow unnecessarily. As transformers are now-a-days designed and manu-

factured to withstand a good amount of lightning surge it is considered better practice to connect them solidly to the lines in groups protected by fuses or an auto-reclose breaker.

Direct acting A.C. trip coils shunted by time limit fuses and auto-reclosers should be used for important feeders. Where the use of a recloser would not be justified T.A.P. breakers may be used. This breaker is designed to provide an efficient and inexpensive means of controlling small transformers and radial feeders. It can control a small current circuit at high voltage upto a maximum of 500 kVA. The essential difference between a T.A.P. and an O.C. B. is the means employed for tripping which in a T.A.P. consists of a fuse in each phase in series with the switch contact.

In our country the rural load being small the fault level will hardly exceed 50 mVA which is the general breaking capacity of a recloser. Co-ordinated use of an auto-recloser with fuses gives satisfactory results consistent with economy.

If an auto-recloser is used without any fuse beyond it, the maximum advantage can be obtained as far as its reclosing feature is concerned as there is no possibility of fuse blowing in the circumstances. (Fig. 10.)

This is satisfactory for temporary faults but will certainly cause more mile outage than a co-ordinated fuse and recloser system when there is a permanent fault. The conventional co-ordinated circuit reclosers are generally 'lock-open' type. There are usually two instantaneous openings then one time delay opening, and then lock open. The other type is "hold closed" recloser which operates very rapidly to clear a temporary fault before the fuse can blow and then holds closed when the proper fuse clears the fault. (Figure 11) This type of recloser is capable of withstanding temporary abnormal currents due to pick-up of load after a shut-down. Unless provided for this, abnormal current might be sufficient to open a lock open type recloser.

Fig. 12 (Time-current curve for autorecloser and fuse co-ordination).

(*o*) *Multiple Earthing on L.T. System*

The use of multipoint earthing of the system neutral will lead to a reduction in cost of earthing the line while improving the voltage regulation.

The neutral should be earthed at each consumer's premises and at the end of each distributor. Where a three-phase system is to be earthed, the earthing of the transformer neutral should be done at one span away from the pole carrying the transformer.

(*p*) *Service connection*

The use of plain stranded aluminium for l.v.o.h. mains and service may be considered. It is considerably cheaper than copper and likely to be so in the future.

The Irish Board use for urban l.v. mains .1 sq. inch cu. equiv. stranded aluminium and .05 sq. inch cu. equiv. stranded aluminium for services .02 sq. inch cu. equiv. A.C.S.R. is used.

For rural l.v. mains the Irish Board use the same conductors as for 11 kV lines i.e. "Robin" (.04 sq. inch, cu. equiv) "Swan" (.02 sq.inch. cu. equiv and for services "Turkey" (.013 sq. inch cu. equiv). They also use an insulated aluminium conductor clipped to the house front to bring supply from the end of the aerial line to the fuse cutout in the consumers' premises. The cutout has tinned or plated terminals which are greased to prevent corrosion. Fig. 13, 14 and 15.

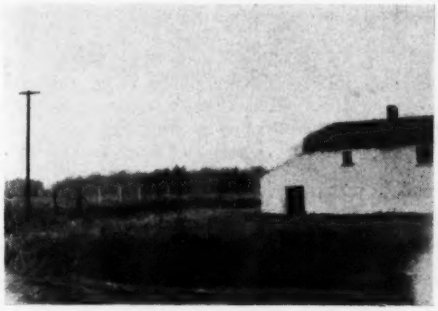


Fig. 13.—Service pole besides low thatched house. Overload wires .02 sq. inch cu equiv. ACSR and .013 sq. inch cu equiv. AL insulated down pole clipped along house front.

Fig. 14.—L T End pole and stay. The aerial service wire are .02 sq. inch cu equiv. ACSR and phase wire is insulated with PRC in the vicinity of roof. Span is normally 60 feet.

Fig. 15.—L T End pole with .013 sq. inch N J S S as clipped down for about 6′ 0″ and then clipped to a catenary of galvanised steel stranded wire. The N J S S is then clipped along the wall of low cottage.

(*q*) *Earthing of Protective Metal Casings on Consumers' Premises.*

In rural net-work where there are no metallic mains for piped water supply it is very difficult to get an earth low enough to blow the consumer's service fuse. One alternative is to use earth leakage relays which cost from £ 3 to £ 4 each and have proved very costly. In Ireland the consumer is allowed to connect his earth protection wire (to frame of appliances) to the Electricity Supply Board's neutral. This ensures his blowing of fuse on fault. This has been found safer and cheaper than earth leakage relays on direct earthing by the consumer. The problem has also arisen lately in towns of Ireland where increasing use is being made of 'non-metallic' water mains and services.

In India the most common method of earthing the steel work of line poles, transformers, etc., is by using cast-iron earth plates, 18 in square and 3/8 in thick, buried at a depth of 5 to 6 ft. The plates may be embedded in crushed coke . Higgs has also shown that pipes and strips are both more effective than plates, a conclusion that has been confirmed by the author in India. For this reason the types of electrodes listed below are recommended for small factories. (*a*) Perforated galvanised tube, 8 ft. long and 1½ in diameter. It is easily installed and lends itself to subsequent treatment with brine to improve earth conductivity. (*b*) Mild steel spike, 8 ft. long and 1 in diameter. This is easiest to instal on consumers' premises where space is restricted. Such electrodes can be driven to depths of 6-8 ft. in a few minutes, except where the subsoil is rocky. The same practice is followed in Ireland where they use 1/2 in diameter galvanised steel rod 6 ft. long. Galvanised steel wire stapled in the pole and wound round the pole is also sometimes used for obtaining good earth. These are cheap and if used enough will give a low earth resistance.

A potential of 30 V is dangerous to humans. The resistance of the earthing system should not therefore exceed 30/I ohms where I is the tripping or fusing current.

A series of measurements shows that a depth of electrode exceeding 8 feet does not materially reduce the resistance whereas a number of electrodes in parallel considerably reduce the resistance, provided that the electrodes are driven in at spacings not less than their depth of setting. (Fig. 16)

For assessing the effectiveness of earthing, earth connections must be properly tested. The most usual methods are :

(*i*) by voltmeter and ammeter, (*ii*) by ohmeter, (*iii*) by a "Megger" tester, and (*iv*) by null method. All are open to the objection that no indication is given of the ability of the fault path to carry sustained current.

The author in the *Electrical Review* reported a method of assessing the effectiveness of earth connection by measuring the potential of the "earth" metal casing while simulating an artificial fault condition on the apparatus intended to be protected.

The equipment incorporating this method is shown in Figure. 17. It comprises an insulated box, housing five test resistors and 60 V high impedance voltmeter, all mounted in a portable case. Extension leads are used for connection to phase, neutral and apparatus frame by means of crocodile clips. After connection and with the control switch on, the selector prod is tapped on to the test-resistor plugs, starting at No 1 until a reading of 30 V is obtained on the voltmeter. If no plug results in a reading below 30 V, the resistance of the earth system will have to be lowered. Testing time is a matter of a few minutes.

Tariff

The principle of designing a tariff to meet the fixed kW costs and permit extended hours of use at a low unit cost still holds good. As the consumption increases, the standing charge becomes less important and the necessary revenue can be recouped by imposing a reduced rate per unit for excess over a primary number.

Proposed Tariff for Rural Supplies

(*a*) For domestic installations the following block tariff is proposed—

For a primary number of units per month .. 5.0 as. per unit

For excess over primary number of units .. 2.5 as. per unit

Note :The number of units on the primary rate will depend on the number of assessable rooms.

(*b*) For electricity for agriculture, cottage industries and other business purposes with a connected load upto 10 B.H.P. the following power rate is suggested.

	Annas per unit	
	For Diesel Station	*For Grid Supply*
For power purposes the first 100 units per B.H.P. per month ..	3.5	2.5
For any unit in excess of the above ..	2.5	1.25

(*c*) Supplies given in special circumstances with demand in excess of 15 kW will be covered by special agreement. For example, in the case of the isolated premises requiring special tapping from a high voltage line, the Supply Organisation can require the excess connection cost to be met by capital contributions, by guaranteed revenue, by line rental or by a combination of any of the above methods.

Some of the advantages of the proposed method under (*a*) and (*b*) above are as follows :—

(1) All consumers would bear a fair proportion of the standing charges and this would standardise tariffs.

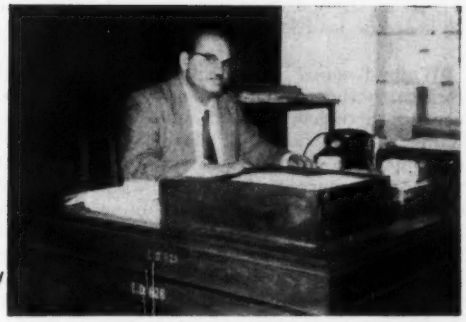
(2) Metering would be simplified, would be more accurate and would cost less.

(*d*) *Tariff for Irrigation*

It is best to offer a tariff which will induce the water pumping to be kept off the peak. An extra

Continued on page 40

Electricity Tariff: Some observations



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Of all the aspects of a public electricity supply business, the one which draws equal amount of attention from the Supply Authorities as well as general public or, strictly speaking, consumers, is tariff. There has never been any lack of interest in this subject but this matter has assumed much greater interest in the present times because there is now an all-out drive to extend the benefits of electricity even in the remotest part of the country. It is a common belief that the consumer can never be satisfied, however low the tariff may be. The importance of an equitable and rational tariff cannot be exaggerated but, it seems it is a perpetual misfortune that although all agree that equitable tariffs are essential for rapid development of electricity supply and industry, they also disagree as to what is meant by an equitable tariff.

It is a known fact that the actual rate chargeable to the consumers must vary from undertaking to undertaking. But very little work has been done to standardise the tariff terminology according to types of load. In most cases, these are fixed by adhoc decisions.

Modern industrial tariff is framed on two-part basis, the total cost being dependant on power and energy or rather fixed and running charges. The power component charge is much greater than the energy component. Hence, load factor plays a very important part in as much as higher load factor tends to distribute the fixed power charge in the larger number of units consumed. It is known that the capital cost of plant and machinery has increased about three to four times than it was before the war. This has naturally resulted in an increase of fixed costs on the undertakings. Therefore, load factor has assumed much greater importance today. An improvement of load factor will almost always result in a cheapening of supply. In this connection it is relevant to say that the two part tariff fixed by the undertakings before the war naturally need revision in the light of the changed ratio of fixed costs to running costs. In some cases fixed costs have remained the same but running costs have changed due to rise in cost of coal. But very few undertakings have made a move in this direction with the result that they are operating under hypothetical conditions.

Like the supply undertaking, the industrial consumers also gain through an improvement of load factor. They naturally gain by the cheapening of overall cost of electricity due to higher load factors. But they gain also in another way. Machinery, etc. during idle periods, cost money in interest, depreciation and maintenance charges and hence the cost of production will fall if the machinery is worked for longer hours. This will particularly be evident where expensive automatic machinery are used because the question of higher cost and lower efficiency of labour resultant from extra working hours does not remain a big problem. That is why off-peak tariff is not so popular amongst industrial consumers of today. Although the consumer gains by way of paying less amount towards electricity bills, he is refrained from working two or three shifts a day, thereby paying a substantial amount of his fixed charges on machinery etc. without any return.

Although an improvement of load factor naturally results in cheapening of cost to the supply undertaking as well as to the consumer, there may probably be an optimum condition in some cases. This is because of diversity factor. The reduction of cost to a consumer due to improvement in his load factor will not wholly reflect on the cost to the undertaking because the gain is largely offset by a reduced diversity. This point will have to be borne in mind while allowing any concession to consumers for improvement in load factor.

In short, the pattern of two-part tariff should change in the new circumstances. It may be necessary to change it further when more and more hydro-electric stations will come into existence, not to speak of atomic power stations when the ratio of fixed cost to running cost will be very high due to extremely high capital cost of such generating stations. We may probably then do away with the energy charge component and charge consumer on the amount of power taken by him. This may involve a greater wastage of energy but the cost of the wastage may not assume any great importance.

There in no hard and fast rule about fixation of the two cost components. But this ratio can be fixed to suit the particular loading conditions. For example, in formulating bulk supply tariff for a consumer whose average load factor is known (say 50%), the

demand charge and energy charge may be so fixed that the two components are equal at 50% load factor. In such a case the incremental cost if the load factor falls from 50% to 40% will be much more than if the load factor falls from 60% to 50%. Therefore the consumer will always have the tendency to keep the load factor about 50%.

While framing any tariff structure the value of service to the consumer should not be ignored. Recently, there has been an increasing trend towards fixing of rates based on marginal cost theory. It is customary to compare the value of output with the value of resources used up. Marginal cost may be defined as the increase in the annual cost which results from supplying one more unit per annum. But the tariff framers may bear in mind that electricity supply industry requires replacement or/and additions to the plant from time to time. Consequently, market fluctuations in the price of plants bring to bear various factors in the cost of electricity in the shape of increased interest and depreciation charges. Therefore it may be that the existing consumers will have to pay less than the new consumers even though energy is used for the same purpose. This will tantamount to showing discrimination and should always be avoided.

There may be other limiting cases too. If a tariff is purely based on marginal cost or cost of production irrespective of the purposes for which electricity is used, there may be a complete change in the pattern of consumption in a few years unless such tariff is weighted by the value of service to the consumer. In such cases, normally industrial consumption will decrease, thereby bringing in under-employment of capital equipment. This in turn will increase cost of production and may upset the economic balance of the undertaking.

Attention has been drawn previously to the importance of fixed charges or rather interest and depreciation charges in the matter of formulating tariff. The idea of providing depreciation charges is to enable the undertaking to purchase and instal a plant of equal capacity and performance at the end of the life of the existing plant. Actually, it has been found that the price of electric machinery is continually on the increase. When a plant is replaced, the cost of the new one is likely to be higher than the cost at which the old one was purchased, say, 20 or 25 years back. This higher cost will be reflected in the tariff which may suddenly increase sharply. So in framing any rate structure provision may be made for such increases in costs which is likely to occur in frequent years due to the reason that old plants, either in generation or in transmission or distribution will need replacement. It is needless to say that such increases in capital expenditure where the depreciation fund does not fully provide for plant replacements, will have to be taken into account by the supply undertakings.

Fixation of tariff has probably some bearing on method of financing. Recently, there is an increasing trend towards extending the benefits of electricity to rural areas. The financing of rural electrification cannot be subjected to the usual test of return on investment. Due to very low standards of living and due to the loads being situated very sparsely, rural electrification cannot be found justified by applying the conventional tests for investments. Moreover, unless the price of electricity is sufficiently low, rural electrification cannot be a success. But unfortunately it has been found that inspite of all efforts to bring down all costs losses are inevitable in the initial years if attractive rates are offered to consumers.

The deficit can be met in many ways. Prospective consumers may be asked to contribute capital in the form of interest-free or low-rate-of-interest loan. The amount may be adjusted against electricity charges over a period of years. Fixed cost on the supply undertaking may thereby be reduced. The other alternative is Government subsidy which may take various forms. Government may advance money at a low rate of interest or make outright payment to cover capital cost for rural electrification. The difference between the cost of electrification and the capitalised value of the anticipated revenue may be paid by Government. The third alternative is that Government may guarantee to make good losses in the initial years. Otherwise, losses in the initial stages may be treated as deferred expenditure to be adjusted against profits in subsequent years. All these steps will lead to a reduction in tariff.

Continued from page 38

Electricity in the Countryside

charge would be imposed if the plant is run during certain specified peak periods viz. from 5 p.m. to 10 p.m.

So as not to penalise the water undertaking for an emergency it may be advisable to offer a two-part tariff on monthly maximum demand terms subject to minimum guaranteed payment.

A typical two-part tariff for a load of 100 kW and above for restricted hours supply would be:

> "Rs. 5/- per kW per month of maximum demand plus running charge of .6 anna per unit with a coal clause adjustment of .007 anna per each -/8/- as increase above the basic cost of coal. Also p.f. surcharge."

Note : If power is used during the peak hours an additional fixed charge of Rs. 5/- per kW of M.D. per month may be levied. It requires special metering in the sense that one additional time-switch is to be incorporated in the meter.

Water pumping loads afford a good means of improving the overall load factor of a supply undertaking and it is essential that no effort be spared to develop this load.

Conclusion

The task of rural electrification which has immense potentialities in stimulating the economic activities of the country cannot be undertaken by the Government alone because of their limited resources. The Government have, therefore, to formulate policy so

as to encourage the flow of private capital for the development of this utility service. One thing that needs emphasis in this connection is that, while the motive behind any private investment is profit, the Government will have to consider whether any investment on its part is worthwhile from the point of view of benefit to the people at large.

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Correction

Page 35: Interchange photos of fig. 1 with fig. 6.
Page 37: Interchange photos of fig. 13 with fig. 14.

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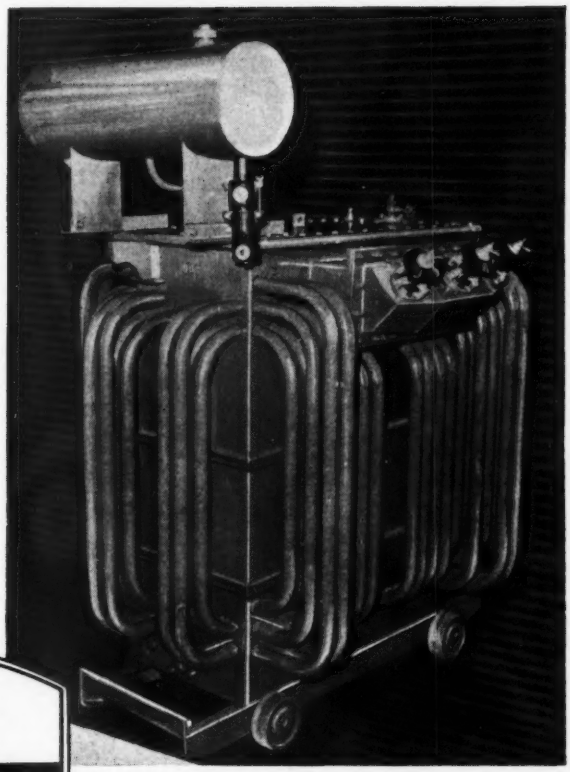

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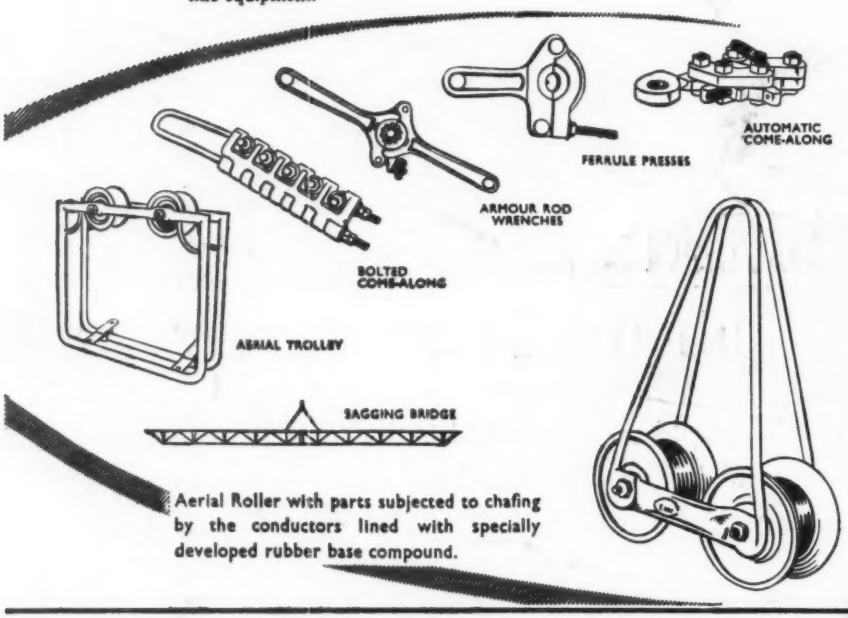

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